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June 1974

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

THE ERTS-1 INVESTIGATION (ER-600)

VOLUME IV — ERTS-1 RANGE ANALYSIS

(REPORT FOR PERIOD JULY 1972 - JUNE 1973)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

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16. Abstract

The Range Analysis Team conducted an investigation to determine the utility of using ERTS-1 data for mapping vegetation-type information on range and related grazing lands. Two study areas within the Houston Area Test Site (HATS) were mapped to the highest classification level possible using manual image interpretation and computer-aided classification techniques.

Rangeland was distinguished from nonrangeland (water, urban area, and cropland) at Level I and was further classified at Level II as woodland versus nonwoodland. Finer classification of coastal features at Level III was attempted with some success in differentiating the lowland zone from the drier upland zone.

Computer-aided temporal analysis techniques enhanced discrimination among nearly all the vegetation types found in this investigation.

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PREFACE

This report is one of seven separate reports prepared by six discipline-oriented analysis teams of the Earth Observations Division at the NASA Lyndon B. Johnson Space Center, Houston, Texas.

The seven reports were prepared originally for Goddard Space Flight Center in compliance with requirements for the Earth Resources Technology Satellite (ERTS-1) Investigation (ER600). The project was approved and funded by NASA Headquarters in July 1972.

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Volume	Title	NASA Number
	A COMPENDIUM OF ANALYSIS RESULTS OF THE UTILITY OF ERTS-1 DATA FOR LAND RESOURCES MANAGEMENT	SP-347 JSC-08455
I	ERTS-1 AGRICULTURAL ANALYSIS	TM X-58117 JSC-08456
II	ERTS-1 COASTAL/ESTUARINE ANALYSIS	TM X-58118 JSC-08457
III	ERTS-1 FOREST ANALYSIS	TM X-58119 JSC-08458
IV	ERTS-1 RANGE ANALYSIS	TM X-58120 JSC-08459
V	ERTS-1 URBAN LAND USE ANALYSIS	TM X-58123 JSC-08460
VI	ERTS-1 SIGNATURE EXTENSION ANALYSIS	TM X-58122 JSC-08461
VII	ERTS-1 LAND-USE ANALYSIS OF THE HOUSTON AREA TEST SITE	TM X-58124 JSC-08463

CONTENTS

Section		Page
1.0	SUMMARY	1-1
1.1	CONVENTIONAL DATA PROCESSING	1-3
1.2	COMPUTER DATA PROCESSING	1-4
2.0	INTRODUCTION	2-1
2.1	OBJECTIVES	2-1
2.2	CLASSIFICATION HIERARCHY	2-1
2.3	SCOPE OF INVESTIGATION	2-5
3.0	STUDY AREAS	3-1
3.1	SNOOK SITE	3-1
3.2	SAN BERNARD SITE	3-4
4.0	DATA UTILIZATION	4-1
4.1	ERTS-1 DATA	4-1
4.2	AIRCRAFT DATA	4-1
5.0	DATA PROCESSING METHODS AND EQUIPMENT	5-1
5.1	CONVENTIONAL DATA PROCESSING	5-1
	5.1.1 Viewing Equipment	5-1
	5.1.2 Creation of Color Enhancements	5-4
	5.1.3 Analysis of Color Enhancements	5-4
5.2	COMPUTER DATA PROCESSING	5-4
	5.2.1 Tape Reformatting	5-6
	5.2.2 Screening and Editing	5-9
	5.2.3 Data Preprocessing	5-9
	5.2.4 LARSYS: Supervised Classification	5-9
	5.2.5 ISOCLS Clustering: Nonsupervised Classification	5-10
6.0	RESULTS AND DISCUSSION	6-1
6.1	CONVENTIONAL PROCESSING	6-1

Section		Page
	6.1.1 Color Enhancements	6-1
	6.1.2 Interpretation	6-2
	6.1.3 Areal Measurements and Regression Analysis	6-5
	6.1.4 Discussion	6-8
6.2	COMPUTER PROCESSING	6-10
	6.2.1 Supervised Classification	6-10
	6.2.2 Nonsupervised Classification	6-23
	6.2.3 General Discussion	6-29
6.3	SUMMARY AND SUGGESTIONS	6-31
	6.3.1 Summary of Work	6-31
	6.3.2 Suggested Improved Methods	6-33
7.0	CONCLUSIONS	7-1
7.1	CONVENTIONAL DATA PROCESSING	7-1
7.2	COMPUTER DATA PROCESSING	7-2
7.3	OBSERVATIONS	7-3
8.0	REFERENCES	8-1
APPENDIX A	WHAT IS RANGELAND	A-1
APPENDIX B	CREATING COLOR ENHANCEMENTS ON THE I^2S MODEL 2000 MCFV	B-1
APPENDIX C	STANDARD LARSYS-TYPE PROCEDURE AT JSC	C-1
APPENDIX D	EXERCISING THE JSC CLUSTERING PROGRAM	D-1
APPENDIX E	I^2S SETTINGS USED ON SPECIFIED FIGURES	E-1
APPENDIX F	LOCATION OF SNOOK SITE FIELDS . . .	F-1
APPENDIX G	LOCATION OF SAN BERNARD SITE FIELDS	G-1

Section		Page
APPENDIX H	COLOR ENHANCEMENTS OF ERTS-1 FILM IMAGERY PRODUCED ON THE I^2S MODEL 2000 MCFV AND ON THE ITEK ACVP . . .	H-1
APPENDIX I	CLASSIFICATION TABLES AND MAPS OF ERTS-1 DIGITAL TAPE DATA USING THE SUPERVISED CLASSIFICATION TECHNIQUE LARSYS	I-1
APPENDIX J	CLUSTER INTERPRETATIONS AND CLASSIFICATION-LIKE CLUSTER MAPS OF ERTS-1 DIGITAL TAPE DATA USING THE NONSUPERVISED PROGRAM ISOCLS	J-1

TABLES

Table		Page
2-I	FIRST-ORDER AND SECOND-ORDER CLASSIFICATION HIERARCHY	2-4
4-I	DISPOSITION OF ERTS-1 DATA RECEIVED	4-2
4-II	SUPPORT AIRCRAFT PHOTOGRAPHY USED	4-3
5-I	REQUIRED TAPE FORMAT CONVERSIONS	5-8
6-I	SNOOK SITE FIELD AREAL MEASUREMENTS PLANIMETERED FROM GROUND-TRUTH MAPS AND FROM COLOR ENHANCEMENTS OF ERTS-1 FILM IMAGERY	6-6
6-II	SAN BERNARD SITE FIELD AREAL MEASUREMENTS PLANIMETERED FROM GROUND-TRUTH MAPS AND FROM COLOR ENHANCEMENTS OF ERTS-1 FILM IMAGERY	6-7
6-III	RESULTS OF LINEAR REGRESSION ANALYSES ON THE AREAL MEASUREMENTS OBTAINED BY PLANIMETERING COLOR ENHANCEMENTS OF ERTS-1 FILM IMAGERY	6-9
6-IV	COMPARISON OF CLUSTER CENTERS OBTAINED FROM CLUSTERING RUNS WITH VARIOUS SAMPLING SCHEMES	6-28
I-I	SNOOK-1 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS	I-2
I-II	SNOOK-1 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS	I-3
I-III	SNOOK-2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS	I-5
I-IV	SNOOK-2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS	I-6
I-V	SB-1 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS	I-8

Table		Page
I-VI	SB-1 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS	I-9
I-VII	SB-2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS	I-11
I-VIII	SB-2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS	I-12
I-IX	SNOOK-1/2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS	I-14
I-X	SNOOK-1/2 SECOND-ORDER CLASSIFICATION PERFORMANCE OF TEST FIELDS	I-15
I-XI	SB-1/2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS	I-17
I-XII	SB-1/2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS	I-18
I-XIII	SNOOK-1 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS	I-19
I-XIV	SNOOK-1 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING CATEGORIES . .	I-20
I-XV	SNOOK-1 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS	I-21
I-XVI	SNOOK-1 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST CATEGORIES	I-22
I-XVII	SNOOK-2 FIRST-ORDER CLASSIFICATION PERFORMANCE	I-23
I-XVIII	SNOOK-2 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING CATEGORIES . .	I-24
I-XIX	SNOOK-2 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS	I-25
I-XX	SNOOK-2 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST CATEGORIES	I-26

Table		Page
I-XXI	SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING CATEGORIES. . .	I-27
I-XXII	SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS.	I-28
I-XXIII	SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST CATEGORIES.	I-29
I-XXIV	SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST CATEGORIES.	I-30
I-XXV	SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS.	I-31
J-I	SNOOK-1 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-1	J-2
J-II	SNOOK-1 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-2	J-4
J-III	SNOOK-1 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-3	J-6
J-IV	SNOOK-2 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-6	J-10
J-V	SB-1 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-7	J-12
J-VI	SB-2 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-8	J-14

FIGURES

Figure		Page
2-1	Schematic drawing of the ERTS-1 rangeland investigation	2-2
2-2	Types of raw data and final products in the rangeland investigation	2-3
2-3	Data flow of the ERTS-1 range investigation using conventional and computer methods	2-7
3-1	Location of study sites within the Houston Area Test Site	3-2
3-2	Infrared aircraft photographic mosaic of the Snook site	3-3
3-3	First-order ground truth of the Snook site	3-5
3-4	Infrared aircraft photographic mosaic of the San Bernard site	3-6
3-5	First-order ground truth of the San Bernard site	3-8
5-1	Itek Additive Color Viewer/Printer (ACVP)	5-2
5-2	International Imaging Systems (I^2S) Model 2000 Multichannel Film Viewer	5-3
5-3	The Earth Resources Interactive Processing System (ERIPS)	5-5
5-4	The Data Analysis Station (DAS)	5-7
6-1	Temporal composite of ERTS-1 data collected over the Snook site. (Single-scene enhancement of film imagery of August 30, November 10, and December 16, 1972)	6-3
6-2	Single-date, single-scene color enhancement of ERTS-1 October 4, 1972, film imagery of San Bernard site	6-4

Figure		Page
6-3	Classification map of San Bernard site using supervised computer classification techniques (ERTS-1 October 4, 1972, digital data)	6-11
6-4	Classification-like clustering map of Snook site using nonsupervised computer classification techniques (ERTS-1 August 30, 1972, digital data)	6-12
6-5	Snook data second-order classification accuracy bar chart for training fields	6-15
6-6	Snook data second-order classification accuracy bar chart for test fields	6-16
6-7	San Bernard data second-order classification accuracy bar chart for training fields	6-17
6-8	San Bernard data second-order classification accuracy bar chart for test fields	6-18
6-9	Snook data overall classification accuracy . .	6-20
6-10	San Bernard data overall classification accuracy	6-21
H-1	I^2S digital multiband composite of bands 5, 6, and 7 (ERTS-1 film imagery of Snook site acquired August 30, 1972)	H-1
H-2	I^2S digital multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery acquired over Snook site November 10,1972)	H-2
H-3	I^2S analog and digital multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery of Snook site acquired December 16, 1972)	H-3
H-4	I^2S analog multiband temporal composite of ERTS-1 film imagery of Snook site - imagery of August 30, November 10, and December 16, 1972	H-4

Figure		Page
H-5	Additive color viewer/printer (ACVP) multiband composite of Snook site (ERTS-1 film imagery acquired August 30, 1972)	H-5
H-6	ACVP multiband composite of Snook site (ERTS-1 film imagery acquired December 16, 1972)	H-6
H-7	ACVP multiband temporal composite of ERTS-1 film imagery of Snook site, acquired August 30, and November 10, 1972	H-7
H-8	I^2S analog multiband composite of San Bernard site (ERTS-1 film imagery acquired October 4, 1972)	H-8
H-9	I^2S digital multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery of San Bernard site acquired November 27, 1972) . . .	H-9
H-10	I^2S digital multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery of San Bernard site acquired November 27, 1972) . . .	H-10
H-11	ACVP multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery of San Bernard site acquired October 4, 1972)	H-11
I-1	CYBER 73 LARSYS classification of Snook-1 data with 2-percent thresholding	I-1
I-2	CYBER 73 LARSYS classification of Snook-2 data with 2-percent thresholding	I-4
I-3	CYBER 73 LARSYS classification of San Bernard-1 data with 2-percent thresholding . .	I-7
I-4	CYBER 73 LARSYS classification of San Bernard-2 data with 2-percent thresholding . .	I-10
I-5	CYBER 73 LARSYS classification of Snook-1/2 temporal data with 2-percent thresholding	I-13

Figure		Page
I-6	CYBER 73 LARSYS classification of San Bernard-1/2 temporal data with 2-percent thresholding	I-16
J-1	Nonsupervised classification map of Snook-1 data using the ISOCLS clustering program (10 clusters)	J-1
J-2	Nonsupervised classification map of Snook-1 data using the ISOCLS clustering program (5 clusters)	J-3
J-3	Nonsupervised classification map of Snook-1 data using the ISOCLS clustering program (8 clusters)	J-5
J-4	Classification map of Snook-1 data obtained by a manipulation of the clustering results of figure J-2	J-7
J-5	First-order classification map of Snook-1 data obtained by manipulation of the clustering results of figure J-3	J-8
J-6	Nonsupervised classification map of Snook data using the ISOCLS clustering program (10 clusters)	J-9
J-7	Nonsupervised classification map of SB-1 data using the ISOCLS clustering program (eight major clusters)	J-11
J-8	Nonsupervised map of SB-2 data using the ISOCLS clustering program (seven major clusters)	J-13

ABBREVIATIONS AND ACRONYMS

ACVP	additive color viewer/printer
BSI	batch system interface
CCT	computer compatible tape
DLMIN	minimum distance between cluster means
DAS	data analysis station
ERIPS	Earth Resources Interactive Processing System
ERTS	Earth Resources Technology Satellite
GSFC	Goddard Space Flight Center
HATS	Houston Area Test Site
I^2S	International Imaging Systems
ISOCLS	JSC clustering algorithm
JSC	Lyndon B. Johnson Space Center
LARS	Laboratory for Application of Remote Sensing
LARSYS	maximum-likelihood classification algorithm
MAXCLS	maximum classes
MCFV	multichannel film viewer
MOPS	multispectral program on passive microwave imaging scanner
MSDS	multispectral data system
m.s.l.	mean sea level
MSS	multispectral scanner
No.	number
pixel	picture elements

PMIS	passive microwave imaging system
PSO	Project Support Office
PTD	Photographic Technology Division
RTCC	real-time computing complex
STDMAX	maximum standard deviation
µm	micrometer

THE ERTS-1 INVESTIGATION (ER-600)

VOLUME IV — ERTS-1 RANGE ANALYSIS

(REPORT FOR PERIOD JULY 1972 - JUNE 1973)

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1.0 SUMMARY

The Earth Resources Technology Satellite (ERTS-1) Range Analysis Team was formed in June 1972 to conduct a 1-year investigation of the utility of ERTS-1 remote sensor data in the earth resources survey program. In particular, the Range Team was assigned to attempt vegetation type-mapping of range and related grazing land. A vegetation type is construed as a collection of vegetation of similar, although not necessarily identical, species dominated by a single characteristic species or a small number of co-dominant species.

To evaluate the utility of ERTS-1 multispectral scanner data, the Range Team attempted two levels of classification, first-order mapping and second-order mapping. First-order mapping was the separation of natural vegetation into the two broad categories of woodland and nonwoodland. Second-order mapping was the classification of the first-order categories into specific vegetation types. The parameters used for quantitative analyses were the accuracies of type identification and of areal measurement. The values of these two parameters were obtained by analyzing at least two sets of data (two dates of the same scene) of two study areas selected in the Houston Area Test Site of Texas. The purpose of performing multidate analysis was an attempt to make

use of the periodic coverage by ERTS-1 and to investigate the possible advantages in data classification and analysis gained by a knowledge of the changes which occurred between different phenological stages.

Two study areas in the Houston Area Test Site were selected for investigation, the Snook site and the San Bernard site. The Snook site lies astride the boundary between the Texas blackland prairie region and the Texas claypan savannah. The features of interest in this site were native stands of post oak, bottomland hardwood, mesquite, native grassland, and planted pastures of bermuda grasses. The San Bernard site is typical of the Gulf Coast marsh region along the Texas and Louisiana coasts. Two distinct vegetation zones existed in this site, the wet lowland zone of marshhay cordgrass and the drier upland zone of gulf cordgrass. Both sites offered the opportunity of a first-order broad classification, while the San Bernard site provided an expected possible second-order classification of vegetation types.

Two classes of techniques were exercised to process the multispectral scanner, data which was recorded on film and digital tape. They were conventional image interpretation techniques and computer-aided data processing techniques. In the first class of techniques, multiband ERTS-1 film imagery was first displayed on optical and electro-optical color film viewers. Color enhancements were created in which the features of interest were accented from the background scene. Photointerpreters were asked to delineate these features (areas that appeared similar), which were then planimetered. Ground-truth information derived from

low-altitude aircraft photography was subsequently used to check the areal measurements obtained. Regression analyses were also made to investigate the significance of the results.

In the second class of techniques, digital tapes were first screened and edited. Processing then took place in two different modes, supervised LARSYS-type classification, and nonsupervised classification using the clustering program ISOCLS. The supervised classification technique requires information to train the computer, while the nonsupervised classification technique requires no training information to produce a classification-like clustering map, in which the clusters are identified in a postprocessing analysis. Both these modes resulted in classification maps and measures of classification performance which were evaluated against ground truth.

Favorable conclusions were reached by examining the limited amount of quantitative results obtained from both types of analyses.

1.1 CONVENTIONAL DATA PROCESSING

a. The examination of the color enhancements created on the film viewers indicated that first-order classification of both sites appeared satisfactory. This meant the site was separated into wooded rangeland, nonwooded open rangeland, cropland, water, and urban area.

b. The separation of the wet lowland zone of marshhay cordgrass from the drier upland zone of gulf cordgrass in the San Bernard site was achieved, which was second-order feature classification.

c. Regression analyses were conducted to correlate the areas interpreted from color enhancements against ground truth. A linear model was developed to predict the true areal measurement from a measurement obtained from a color enhancement created on the available film viewers. However, the standard errors of the areal measurements were as high as 250 hectares (530 acres) when measuring areas as large as 10,500 hectares (22,500 acres). The inordinately large error figures were believed to be due to the fuzziness in boundaries between the extremely complex vegetation zones, as well as to the less-than-ideal quality of the color enhancements created in this investigation.

d. Some features, such as cropland, were enhanced and accented from the background more vividly in the temporal enhancements than in signal-date enhancements.

1.2 COMPUTER DATA PROCESSING

a. The classification accuracies of training fields were high. By aggregating second-order fields into first-order categories, the first-order classification accuracies appeared even higher, with values as high as the mid-ninety percentile.

b. The temporal analyses provided even better classification accuracies for the training data as well as less confusion between training classes.

c. The classification accuracies of test fields were not as high as those of training fields. Again, first-order classification accuracies appeared higher than second-order

accuracies. The choice of nonrepresentative test fields was believed to be due to the lack of intensive ground truth and spot-checked fields.

d. First-order classification was generally satisfactory for both sites; i.e., separation into wooded rangeland, nonwooded rangeland, cropland, and water. In the San Bernard site, the soil moisture content in the marshhay cordgrass and that in the gulf cordgrass was sufficiently different to permit separation between the two classes.

e. The clustering results were very useful because no information was required to identify spectrally homogeneous areas in the data. Further still, this nonsupervised classification technique allowed the grouping of unknown and/or even subtle features into spectrally unique groups which further analysis could perhaps assign significance. A sampling technique to reduce the computation time of the clustering process was attempted which resulted in positive conclusions.

f. The clustering results appeared to be very satisfactory for first-order classification, and to a certain extent for second-order classification. A quantitative analysis of the classification accuracies was not made due to the lack of intensive ground truth.

From the limited experience gained by this investigation, both the conventional photointerpretation processing methods and the computer processing methods had their merits, even though the latter class of techniques seemed to be more

amenable to systematic quantitative analyses. The following positive findings were determined:

1. The Range Team demonstrated the utility of the ERTS-1 MSS data for mapping vegetation types satisfactorily into first-order broad categories. Rangeland comprised of woodland and nonwoodland was distinguished from nonrangeland comprised of water, urban area, and cropland.

2. Second-order finer classification was also possible, depending on the existence of certain not-yet-fully-understood characteristics of the features, such as soil moisture content. The demonstration of the ability to separate the wet lowland zone from the drier upland zone, e.g. in the San Bernard site, should be of significant value to users interested in mapping wetland features in coastal areas.

3. Temporal analysis, particularly using computer-aided techniques in processing digital data, enhanced the discrimination between nearly all the vegetation types in this investigation. This conclusion supported the prediction from mathematical theories.

2.0 INTRODUCTION

2.1 OBJECTIVES

The ERTS-1 Range Analysis Team conducted a 1-year investigation to determine the utility of ERTS-1 remote-sensor data for vegetation-type mapping of range and related grazing land.

A vegetation type is a collection of vegetation of similar, although not necessarily identical, species dominated by a single characteristic species or a small number of co-dominant species. The utility of the ERTS-1 data was evaluated using the parameters of the accuracies of type identification and of areal measurement.

A schematic drawing of this investigation and an illustration of the types of data and products are presented in figures 2-1 and 2-2.

2.2 CLASSIFICATION HIERARCHY

Rangeland was equated to woodland (stands of trees) and nonwoodland (open grassland and brushland). Many tree types and numerous vegetation species could be associated with these broad categories. A detailed definition is presented in appendix A.

Two natural levels of classification were demanded in this investigation, first-order mapping and second-order mapping (table 2-I). First-order mapping was the categorization of natural vegetation into the broad categories of

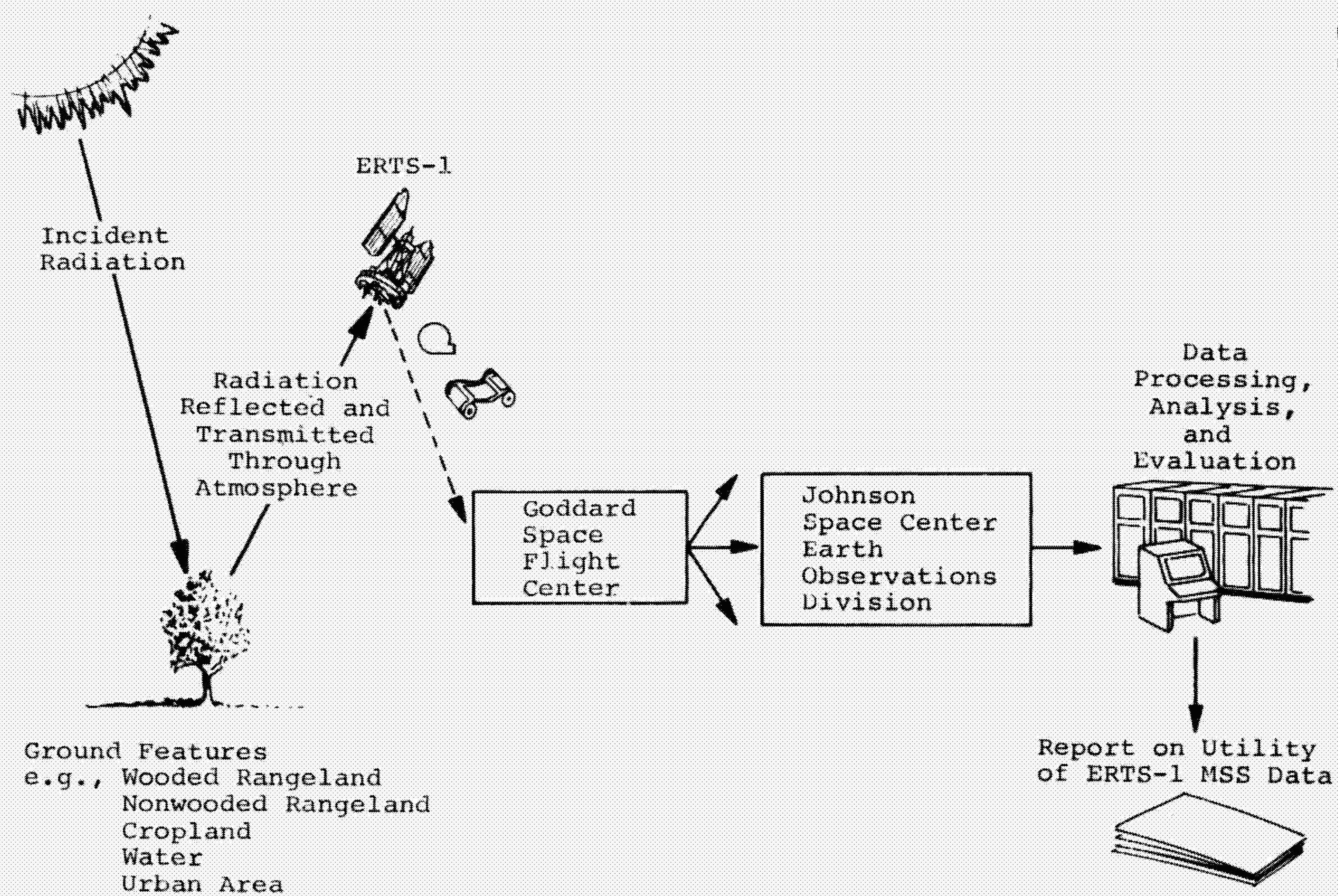

Figure 2-1.— Schematic drawing of the ERTS-1 rangeland investigation.

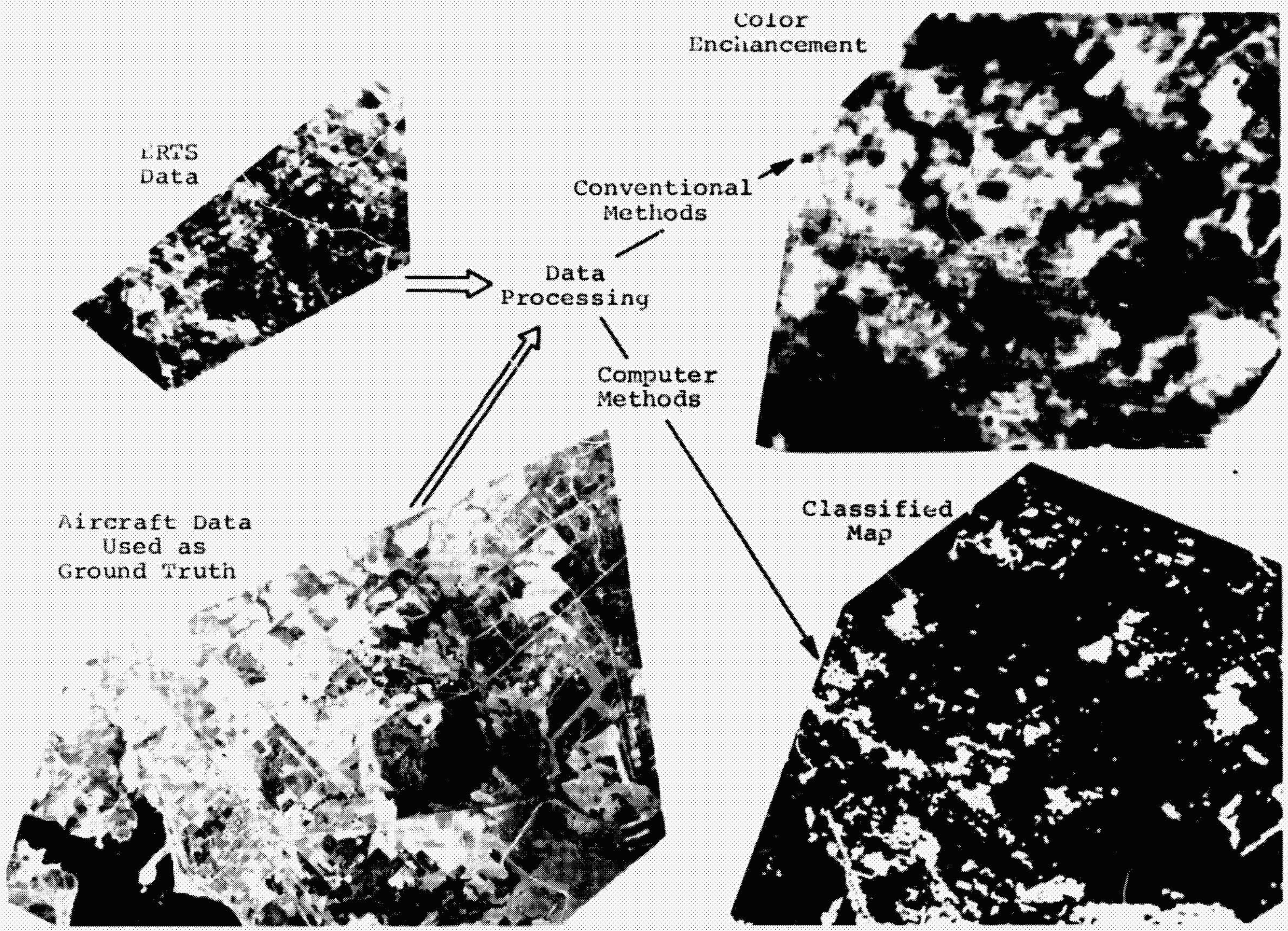

Figure 2-2.- Types of raw data and final products in the rangeland investigation.

woodland and nonwoodland, as opposed to nonrangeland, which was considered to be composed of cropland, water, and urban area. The first-order categories were further classified into specific classes in the process of second-order mapping.

TABLE 2-I.- FIRST-ORDER AND SECOND-ORDER CLASSIFICATION HIERARCHY[a]

First Order		Second Order
Rangeland	Woodland	Post-oak stands Mesquite stands Bottomland hardwood
	Nonwoodland	Open pastures Abandoned cropland Gulf cordgrass Smut cordgrass Marshhay cordgrass Burned area, previously cord-grass Cultivated bermuda fields Wet bottomland
Non-rangeland	Water	Deep-sea water Coastal water Inland water, etc.
	Cropland	Rice fields, etc.
	Urban area	Residential, etc.

[a]Although not necessarily typical of range features, the tabulated second-order features under the class of rangeland were chosen because they were dominant in the two study sites. Attempt was not made in this investigation to classify second-order features of nonrangeland, thus they are not defined in detail.

2.3 SCOPE OF INVESTIGATION

The investigation area was the Houston Area Test Site (HATS) in Texas. Two sites within HATS were selected for study. While the results provided insight into the general utility of ERTS-type data, they might not be directly applicable to ecosystems of totally different structures in other rangeland areas of the United States.

Two to three sets of data (two to three dates of the same scene) of each of the two study sites were investigated. The data sets spanned a period of 3-1/2 months, from late August to mid-December 1972. This offered the opportunity of temporal analyses, which were conducted to determine the utility of the cyclic coverage of the ERTS-1.

The term temporal analysis is used in this investigation to connotate the analysis of composed data sets. Such a composed data set is a unique set of data that is derived from considering a feature to be described by a temporal signature. The term temporal signature is used to construe the characteristic of a feature across time, with a time-span yet to be specified. A simplified example is that of deciduous trees: the tree has a 1-year temporal characteristic of being light green in spring, richly deep green in summer, yellow in autumn, and brown in winter. Temporal analyses were conducted to identify the possible advantages in data classification and analysis gained by a knowledge of the changes which occurred between different phenological stages.

Since limited manpower and resources prohibited complete and detailed on-the-spot ground-truth acquisition, low-altitude aerial photography was used as a substitute. On these photographs, homogeneous areas were delineated, from which selected targets were point-checked on the ground. The identification of the existing dominant vegetation type or types in the targets subsequently produced controlled ground-truth information on the study sites.

The ERTS-1 multispectral scanner (MSS) data in the forms of film imagery and digital tape data were used in this investigation. These data were acquired from the Goddard Space Flight Center (GSFC).

The film data were analyzed by conventional photointerpretation techniques and digital tape data were processed by computer-aided techniques. A schematic drawing illustrating the data flow in this investigation using the two classes of methods is shown in figure 2-3.

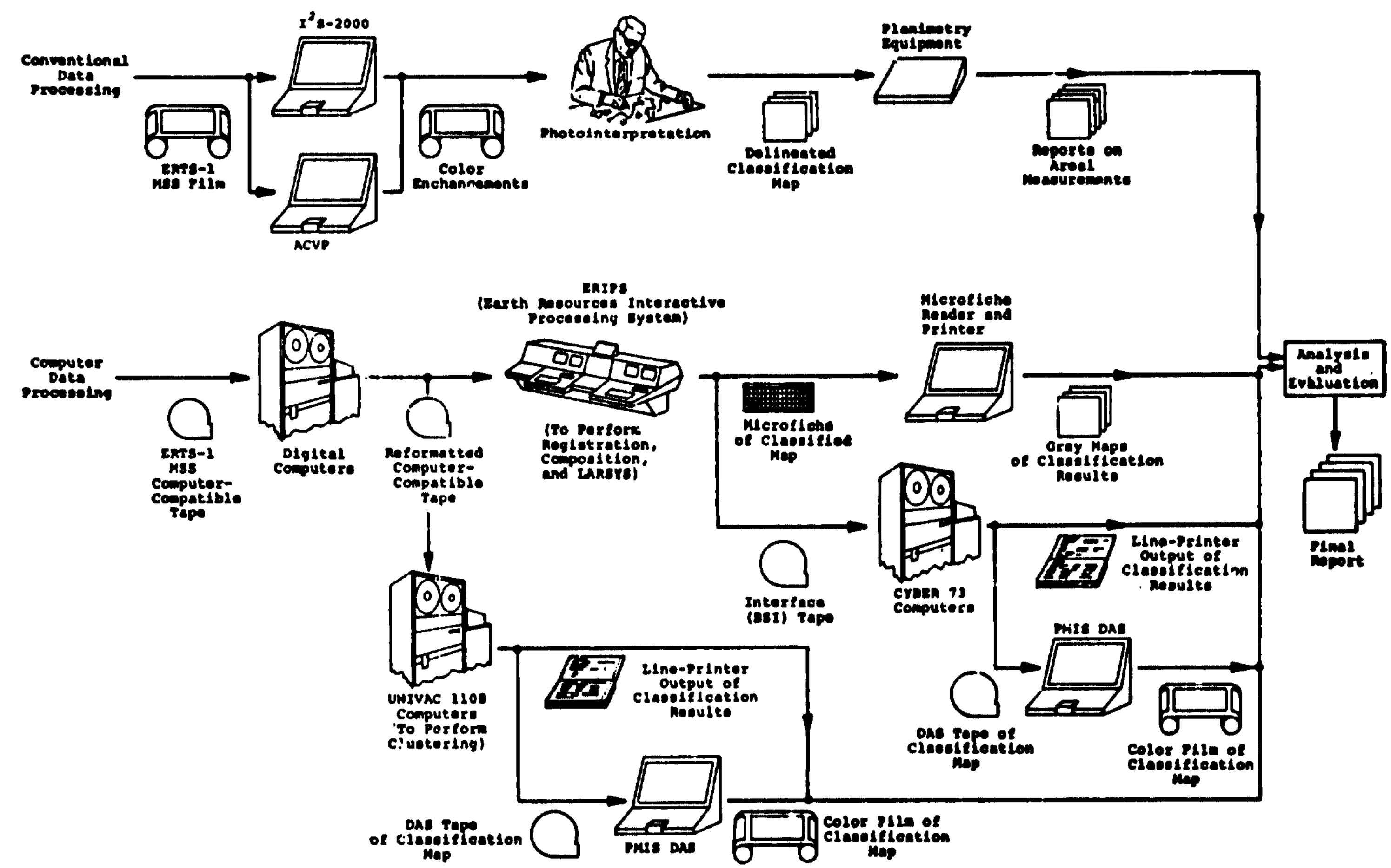

Figure 2-3. - Data flow of the ERTS-1 range investigation using conventional and computer methods.

3.0 STUDY AREAS

The two areas within HATS selected for study, the Snook site and the San Bernard site, are described in detail below.

3.1 SNOOK SITE

The Snook site is northeast of Somerville, Texas, in Burleson County (figures 3-1 and 3-2). The coordinates of the approximate center of the area are latitude 30°26' N. longitude 96°27'W.

The total area of the site is approximately 300 square kilometers (116 square miles). The Snook site lies astride the boundary between the Texas blackland prairie region and the Texas claypan savannah. Thus, this site afforded the opportunity to examine the separability of plant communities characteristic of each region in the ERTS-1 imagery.

The total area of the blackland prairie is about 51,800 square kilometers (20,000 square miles), most of which is in central Texas. Over two-thirds of the area is cropland, about one-sixth is pasture, and the remainder is low woodland. The woodland areas are characterized by such noncommercial species as pecan (*Carya sp.*), oak (*Quercus sp.*), hackberry (*Celtis sp.*), and elm (*Ulmus sp.*).

The Texas claypan savannah, about 33,700 square kilometers (13,000 square miles) in size, is about one-half woodland. Most of the wooded area is in post oak (*Quercus stellata* Wagenh.) with an understory of yaupon (*Ilex*

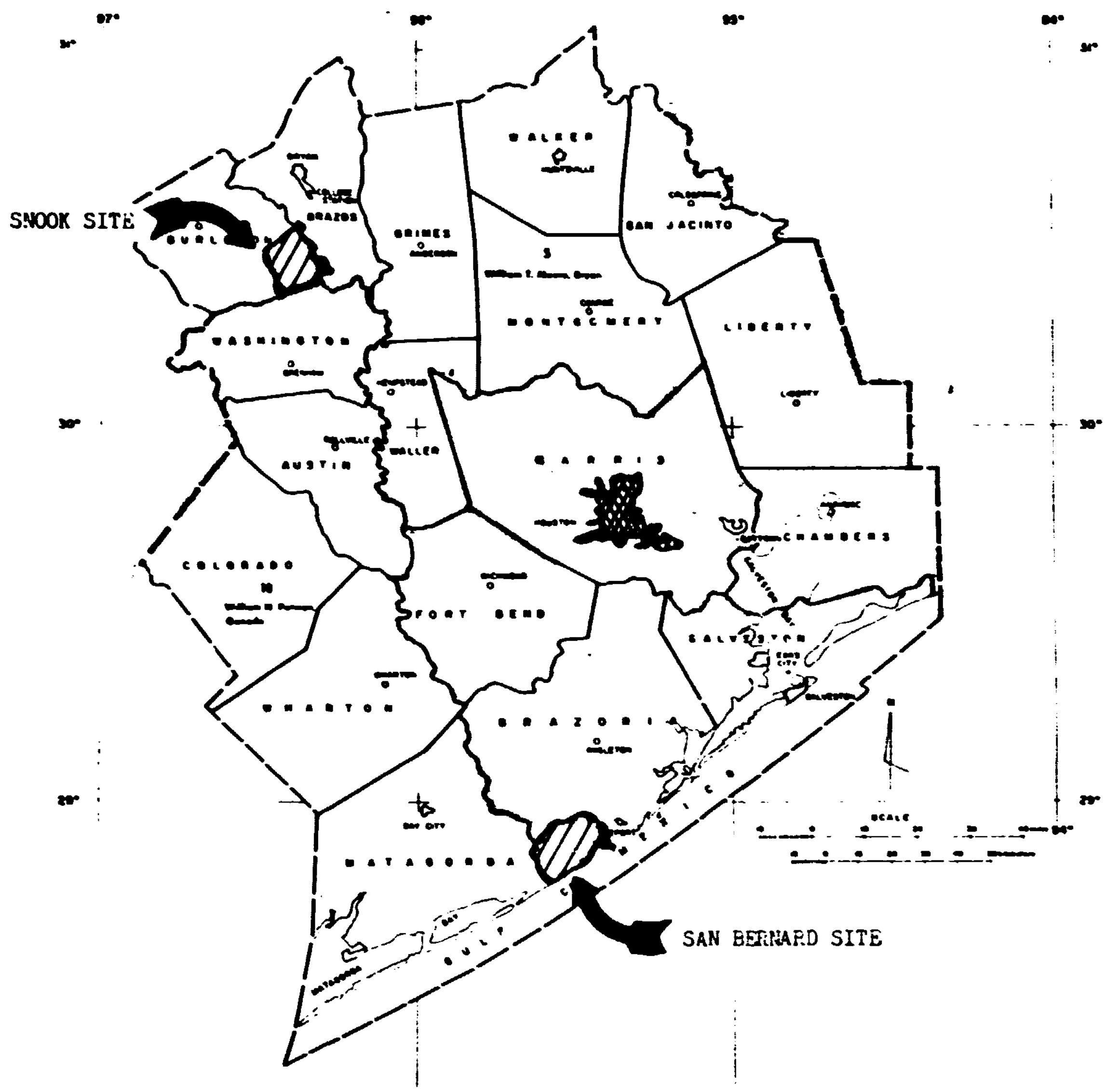

Figure 3-1.— Location of study sites within the Houston Area Test Site.

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Figure 3-2.- Infrared aircraft photographic mosaic of the Snook site.

vomitoria Ait.) and winged elm (*Ulmus alata* Michx.). Some hardwood forest occurs in the wetter bottomlands. The more open areas of post oak have a grass understory of brownseed paspalum (*Paspalum plicatulum* Michx.), silver bluestem (*Andropogon saccharoides* Swartx), and little bluestem (*Andropogon Scoparius* Michx.). About one-half the area had been cleared and cultivated in the past, but most of the land has returned to pasture of native grasses and forbs.

The second-order features (vegetation types) to be investigated on the Snook site included native stands of post oak, bottomland hardwood, abandoned cropland, mesquite (*Prosopis* sp.), and planted pastures of bermuda grass. A first-order breakdown of the ground-truth information on the site is shown in figure 3-3.

3.2 SAN BERNARD SITE

The San Bernard site is west of the San Bernard River outlet on the Gulf of Mexico (figure 3-4). Its approximate center is located at latitude 28°42'N. longitude 95° W.

The San Bernard site, about 370 square kilometers (143 square miles) in area, is typical of the Gulf Coast marsh, a 20,700 square kilometer (8,000 square mile) region along the Texas and Louisiana coasts. Virtually none of the area is farmed, but livestock grazing is a significant seasonal use of the drier areas. Hunting and fishing are important recreational uses of the region, and trapping furbearers is of local economic importance.

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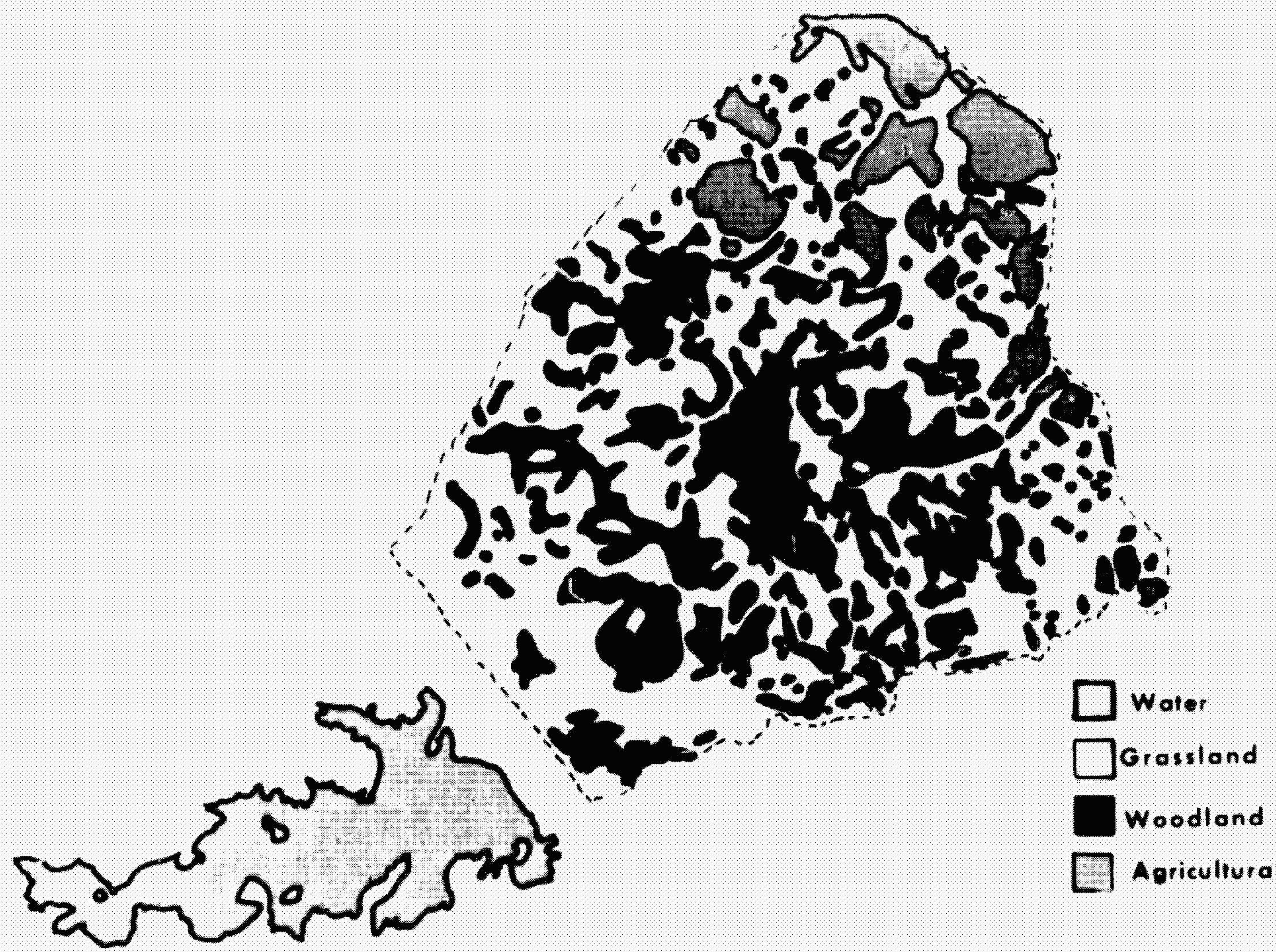

Figure 3-3.- First-order ground truth of the Snook site.

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Figure 3-4.- Infrared aircraft photographic mosaic of the San Bernard site.

The coastal marsh has two fairly distinct vegetation zones, marshhay cordgrass (*Spartina patens* Ait. Muhl.) and smooth cordgrass (*Spartina alterniflora* Loisal.). These zones occur on the salt marsh site immediately adjacent to the Gulf waters from 0 to 2 inches mean sea level (m.s.l.) and are usually inundated during high tide. Adjacent to the salt marsh is a slightly higher zone (2 inches to 3 feet m.s.l.), dominated by gulf cordgrass (*Spartina spartinae* Trin. Merr.). Each of these two vegetation zones was a second-order feature in the investigation. A first-order breakdown of the ground-truth information on the site is shown in figure 3-5.

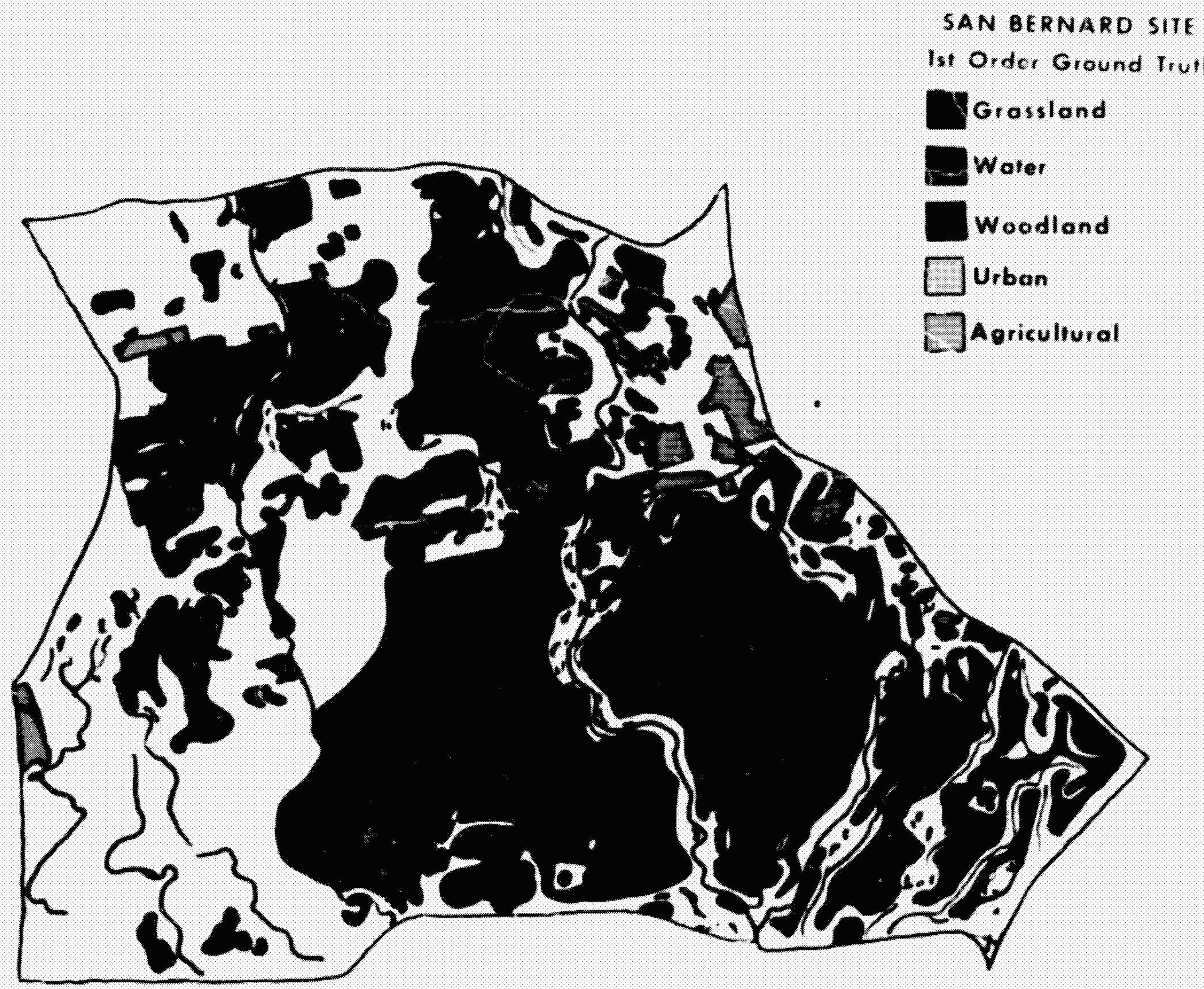

Figure 3-5.- First-order ground truth of the San Bernard site.

4.0 DATA UTILIZATION

The ERTS-1 MSS data acquired from the GSFC used for analysis were in the form of film imagery and digital tapes. Aircraft data were used to create controlled ground-truth information.

4.1 ERTS-1 DATA

The ERTS-1 MSS data were collected in the four spectral bands 4 through 7 (equivalent to channels 1 through 4 in other references). Band 4 (channel 1) covers the spectral band of 0.5 to 0.6 micrometer (μm), band 5 (channel 2) covers 0.6 to 0.7 μm, band 6 (channel 3) covers 0.7 to 0.8 μm, and band 7 (channel 4) covers 0.8 to 1.1 μm. These four bands cover most of the visible spectrum and part of the reflective infrared spectrum.

The ERTS-1 data in film and digital tapes which were received and processed are tabulated in table 4-I.

4.2 AIRCRAFT DATA

Aircraft color and color-infrared photography was used as ground-truth information on the distribution of the vegetation types being studied. The photography was obtained from three NASA missions in three photographic scales. Refer to table 4-II for the mission numbers, dates on which missions took place, the coverage, the altitudes of flight, camera systems, film types, and the scales of the imagery.

TABLE 4-I.- DISPOSITION OF ERTS-1 DATA RECEIVED

Site	Scene Number	Date	Date Received For Analysis		Conventional Processing		Computer Processing	
			Film	Tape	No. of ACVP Enhancement	No. of MCFV Enhancement	No. of Cluster Maps	No. of Classification Maps
Snook	1038-16303	8/30/72	12/26/72	12/9/72	8	4	10	3
Snook	1110-16311	11/10/72	1/17/73	-	3	5	-	-
Snook	1128-16311	11/28/72	3/2/73	2/9/73	1	-	13	3
Snook	1146-16311	12/26/72	3/26/73	-	3	3	-	-
San Bernard	1073-16251	10/4/72	1/4/73	1/19/73	4	6	7	3
San Bernard	1127-16260	11/27/72	4/14/73	4/20/73	-	4	2	2

TABLE 4-II.- SUPPORT AIRCRAFT PHOTOGRAPHY USED

Mission	Date	Site	Altitude	Camera	Film	Scale
208	August 1972	San Bernard	60,000 feet	RC-8 and Zeiss	S0365 and 2443	1/60,000 1/120,000
		Snook	60,000 feet	RC-8 and Zeiss	S0365 and 2443	1/60,000 1/120,000
216	October 1972	San Bernard	10,000 feet	RC-8	S0365 and 2443	1/20,000
		Snook	10,000 feet	RC-8	S0365 and 2443	1/20,000
220	November 1972	Snook	60,000 feet	RC-8 and Zeiss	S0365 and 2443	1/60,000 1/120,000

All delineation and subsequent planimetry of ground-truth features were done on positive prints of the photographs. First-order type mapping for the two study sites was done on 1:120,000 scale photographs. Second-order intensive mapping was done on low-altitude 1:20,000 scale photographs.

5.0 DATA PROCESSING METHODS AND EQUIPMENT

Two classes of techniques were exercised to process the MSS data. Conventional photointerpretation methods were employed to process film data, while computer data processing methods were employed to process digital tape data.

5.1 CONVENTIONAL DATA PROCESSING

Conventional photointerpretation data processing of film imagery data basically involved two steps, creating color enhancements of the imagery on some multichannel viewing equipment and analysis of the color enhancements.

5.1.1 Viewing Equipment

Two machines were used to create color enhancements, the Itek Additive Color Viewer/Printer (ACVP) shown in figure 5-1 and the International Imaging Systems (I^2S) Model 2000 Multichannel Film Viewer (MCFV) shown in figure 5-2. The former is an optical multiband viewing equipment. The latter is an electro-optical imaging equipment.

The Itek ACVP accepts up to four single-band black-and-white transparencies and projects them through different colored filters onto a common viewing surface. An 8- by 10-inch film holder fits over the viewing surface to photograph the color image constructed.

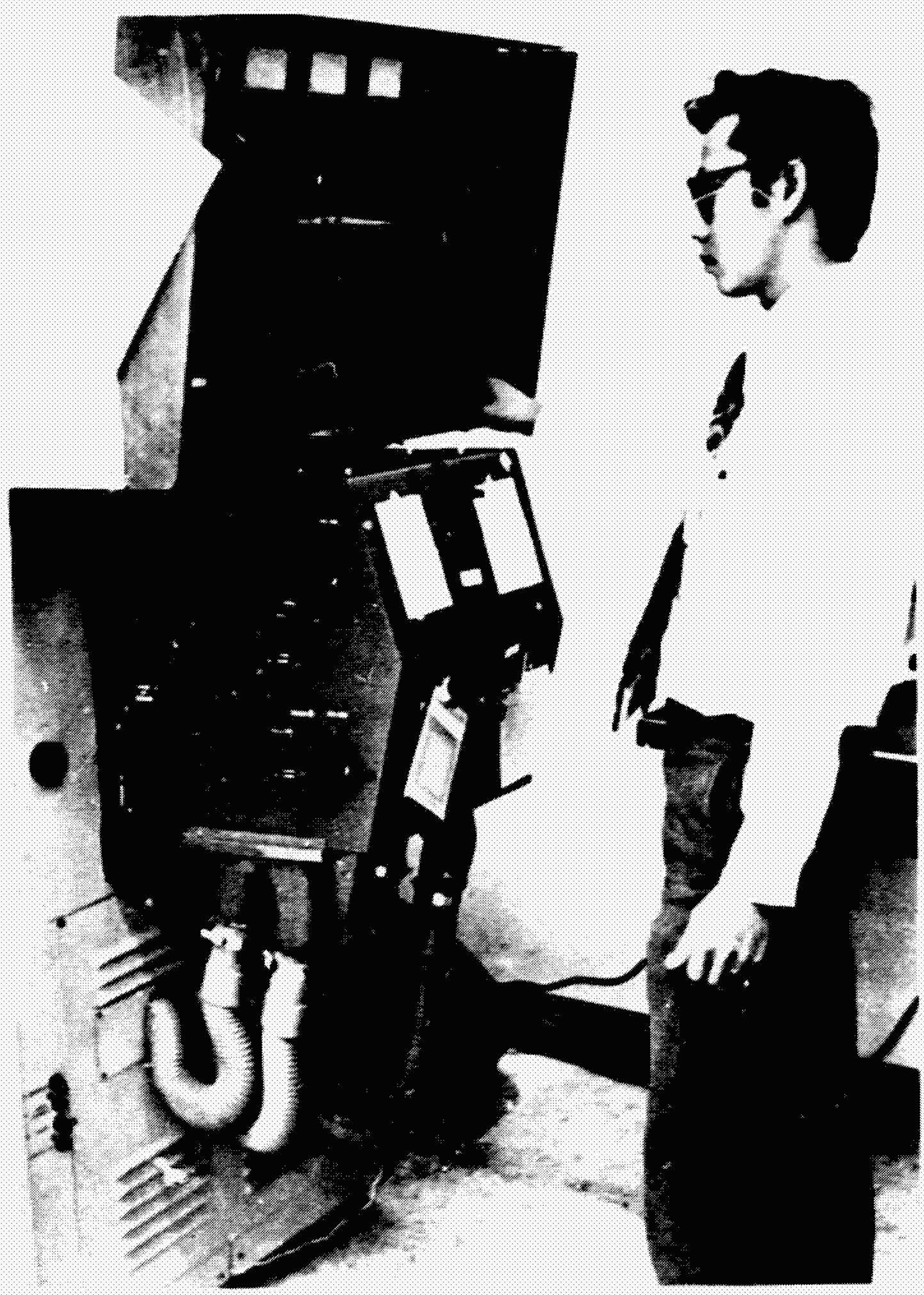

Figure 5-1.- The Itek Additive Color Viewer/Printer (ACVP).

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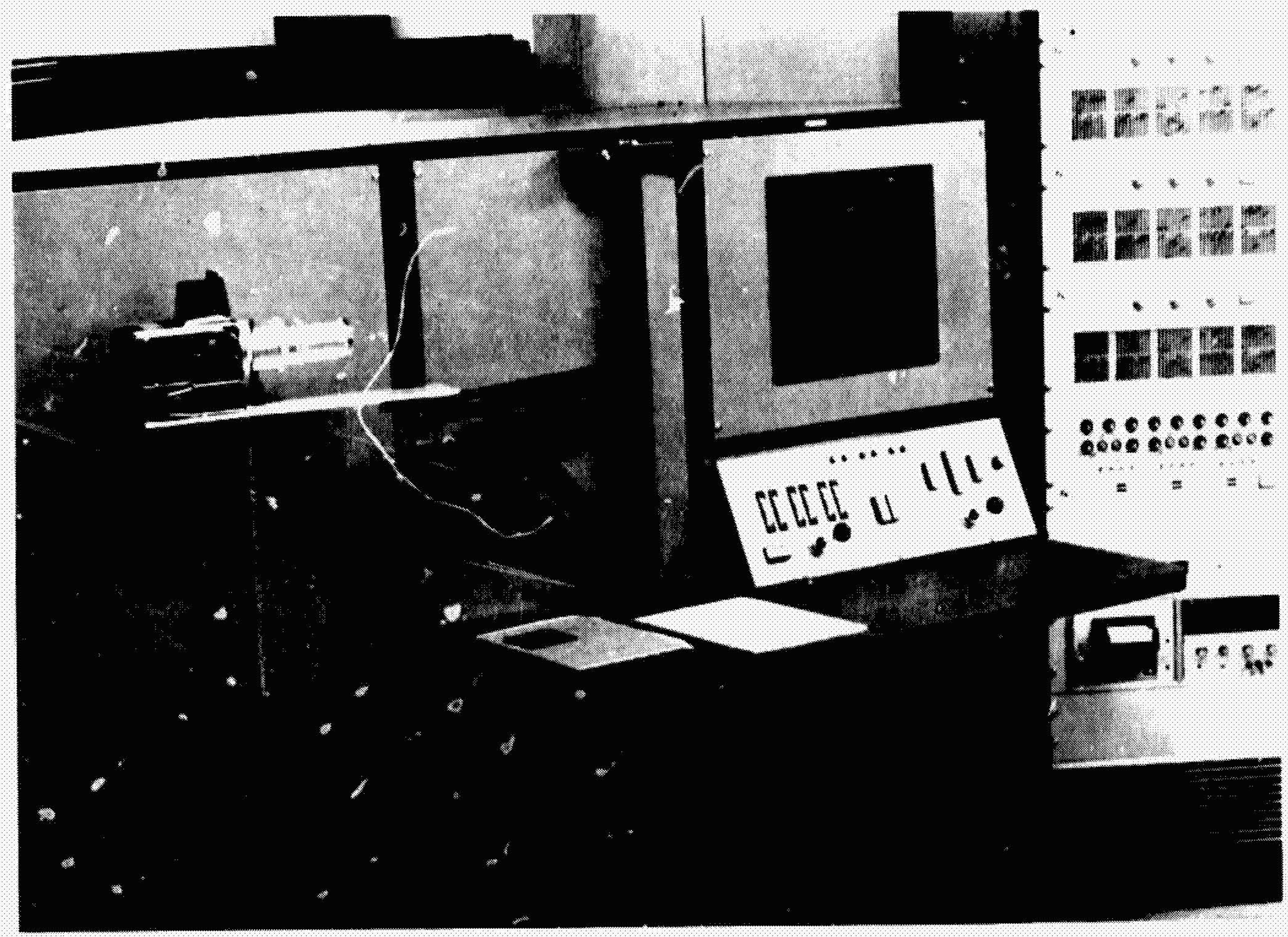

Figure 5-2.- International Imaging Systems (I^2S) Model 2000 Multichannel Film Viewer.

The I^2S Model 2000 MCFV is a more sophisticated type of equipment. A discussion on the operation and capability of the I^2S machine is found in appendix B and in reference 1.

5.1.2 Creation of Color Enhancements

A false color display of the image scene enhances the features of interest from the background scene. The rationale of creating good color enhancements is discussed in appendix B. The two instruments described above were used for this process.

5.1.3 Analysis of Color Enhancements

After the color enhancements were made, they were interpreted by three persons not associated with the Range Team and unfamiliar with the study sites. The features that appeared similar were delineated and planimetered to generate area figures. Ground-truth information was compared with the areal measurements obtained. A regression analysis was then performed to investigate the accuracy and statistical significance of these results.

5.2 COMPUTER DATA PROCESSING

The computer processing facilities which were used to process the digital tape data were:

a. UNIVAC 1108 computers

b. IBM 360/75 computers

c. CDC CYBER 73 computers

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Figure 5-3.- The Earth Resources Interactive Processing System (ERIPS).

d. The Earth Resources Interactive Processing System (ERIPS), which is accessed through two Hazeltine terminals to the IBM 360/75 computers in the Real-time Computing Complex (RTCC) of the NASA Lyndon B. Johnson Space Center (JSC) (figure 5-3)

e. The Purdue Terminal, a remote computer terminal connected to the IBM 360 computing facilities and software packages at Purdue University of Lafayette, Indiana

f. Two Data Analysis Sections (DAS), on which Computer Compatible Tapes (CCT) of multispectral data are screened and edited (figure 5-4)

The software programs which were used for the classification and analysis activities are discussed in paragraphs 5.2.4 and 5.2.5.

The following describes the five general data processing activities:

1. Tape reformatting
2. Screening and editing data tapes
3. Data preprocessing (data registration and composition)
4. Supervised classification (LARSYS)
5. Nonsupervised classification (ISOCLS clustering)

5.2.1 Tape Reformatting

The lack of a common format among all data generation and processing systems at the JSC required that certain

Figure 5-4.- The Data Analysis Station (DAS).

TABLE 5-I.- REQUIRED TAPE FORMAT CONVERSIONS

From	To	Purpose
GSFC	MSDS	To allow ERTS data to be screened on the DAS.
GSFC	LARSYS II	To allow ERTS data to be processed by the programs on the UNIVAC 1108 and the IBM 360/75 computers.
MSDS	LARSYS II	To allow DAS edited tapes to be processed by the programs on the UNIVAC 1108 and the IBM 360/75 computers.
9-track	7-track	To interface the UNIVAC 1108 (mostly 7-track) with the IBM 360/75 (mostly 9-track) computers.

data format conversions be performed. These conversions and their justifications are shown in table 5-I.

5.2.2 Screening and Editing

The ERTS data tapes in multispectral data system (MSDS) format were screened on the PMIS DAS. The selected study sites were then edited to obtain the desired scale. Edited copies of the image at the same scale and at a 2:1 scale were usually created.

5.2.3 Data Preprocessing

Image-to-image data registration is a requirement for temporal analysis and was available on the ERIPS system. After two images of the same study site were registered, an ERIPS image composition process combined the two 4-channel data tapes into an 8-channel tape.

Another preprocessing activity that was considered was atmospheric correction to remove the effect of haze in the atmosphere and to accommodate the effect of seasonal changes in the Sun angle. This activity was not carried out because of the lack of time and the delayed availability of the atmospheric correction software. The removal of atmospheric effects was also shown not to affect the single-date classification of small areas such as the present study sites (ref. 2).

5.2.4 LARSYS: Supervised Classification

The ERIPS interactive system was made available to Earth Resources users in February 1973. Its software

includes a set of programs for multispectral pattern recognition called LARSYS. The programs were written by the Laboratory for Applications of Remote Sensing (LARS) at Purdue University. The supervised classification technique (ref. 3) involves the following steps:

a. Select training fields.

b. Measure the spectral characteristics of the training fields by generating statistics of their spectral distributions.

c. Select the channels which will best discriminate between various classes.

d. Classify the test data using the maximum likelihood classifier (ref. 4).

e. Display the classification results on the line printer and on the PMIS DAS where color film copies can be generated.

Refer to appendix C for a detailed description of a standard LARSYS-type procedure.

5.2.5 ISOCLS Clustering: Nonsupervised Classification

Another method of classifying multispectral data is nonsupervised classification or clustering with program ISOCLS (refs. 5 and 6). The program groups data points that are spectrally similar to create a classification-type cluster map. The clusters are then identified with the

help of ground truth. This process was carried out in the following steps.

a. The data were input to the Univac 1108 ISOCLS program and clustered.

b. A cluster map was produced on the line printer and on color film on the PMIS DAS.

c. The clusters were identified by checking selected areas against ground truth and color coded to produce classification maps. This process is discussed in more detail in paragraph 6.2.2.

Appendix D provides a detailed description of the procedure to exercise the clustering program.

6.0 RESULTS AND DISCUSSION

This section consists of three main subsections. The first subsection presents the processed output products using conventional photointerpretation techniques and the analyses of these film products. The second subsection presents the computer data-processing results of the digital tape data. The output products derived by both supervised and nonsupervised classification techniques are discussed. A general discussion of these two computer methods is also included. The third subsection summarizes the work that was done and offers suggestions for improving future studies.

The relevant photographic products of this investigation are documented in appendixes H, I, and J. Only four representative classification maps are illustrated in this section. The classification results and cluster interpretations are also tabulated in appendixes I and J, and a summary of their analyses is presented in this section.

6.1 CONVENTIONAL PROCESSING

6.1.1 Color Enhancements

Single-date, single-scene color enhancements were created on film viewers using different spectral bands of the same single-date film imagery on the different channels of the viewer. For example, band 4 of the ERTS-1 imagery was placed on the blue channel of the viewer, band 5 on the green channel, and band 7 on the red channel. Temporal color enhancements; i.e., multidate, single-scene enhancements, were created on the viewer using scenes of different

dates on different channels of the viewer. For example, a temporal composite of three dates could be made by placing band 4 of the second date on the blue channel, band 6 of the first date on the green channel, and band 7 of the third date on the red channel.

Typical color enhancements from the ERTS-1 film imagery are presented in figure 6-1 for the Snook site and in figure 6-2 for the San Bernard site.

6.1.2 Interpretation

A good enhancement which offered high contrast between different features was not easy to create due to the complexity of the second-order range features in the Snook site. Figure 6-1 in particular shows the fuzziness of the boundaries and the gradual transition of color shades between features. However, first-order separation of post-oak stands, wooded rangeland, bermuda fields, nonwooded rangeland, water, and cropland could be detected. The temporal composite of figure 6-1 indicates that some features, such as cropland, are more vividly enhanced and accentuated from the background scene in this temporal composite than in the three corresponding single-date, single-scene composites (figures H-1, H-2, and H-3).

Figure 6-2 shows the separation of the wet lowland zone of marshhay cordgrass from the drier upland zone of gulf cordgrass in the San Bernard site. These were second-order features under the category of nonwooded rangeland. Woodland, water, and urban areas were also detectable.

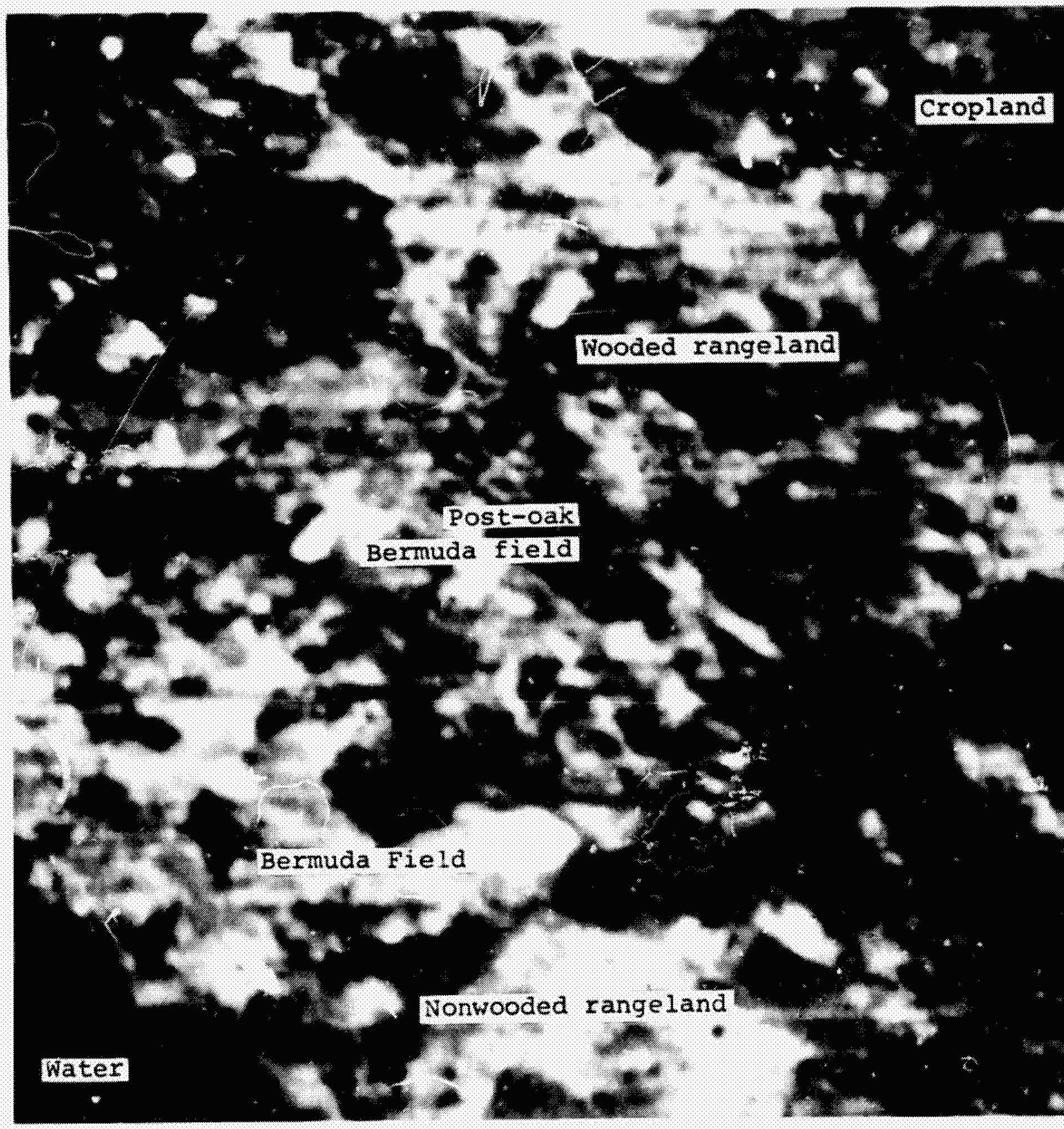

Figure 6-1.- Temporal composite of ERTS-1 data collected over the Snook site. (Single-scene enhancement of film imagery of August 30, November 10, and December 16, 1972).

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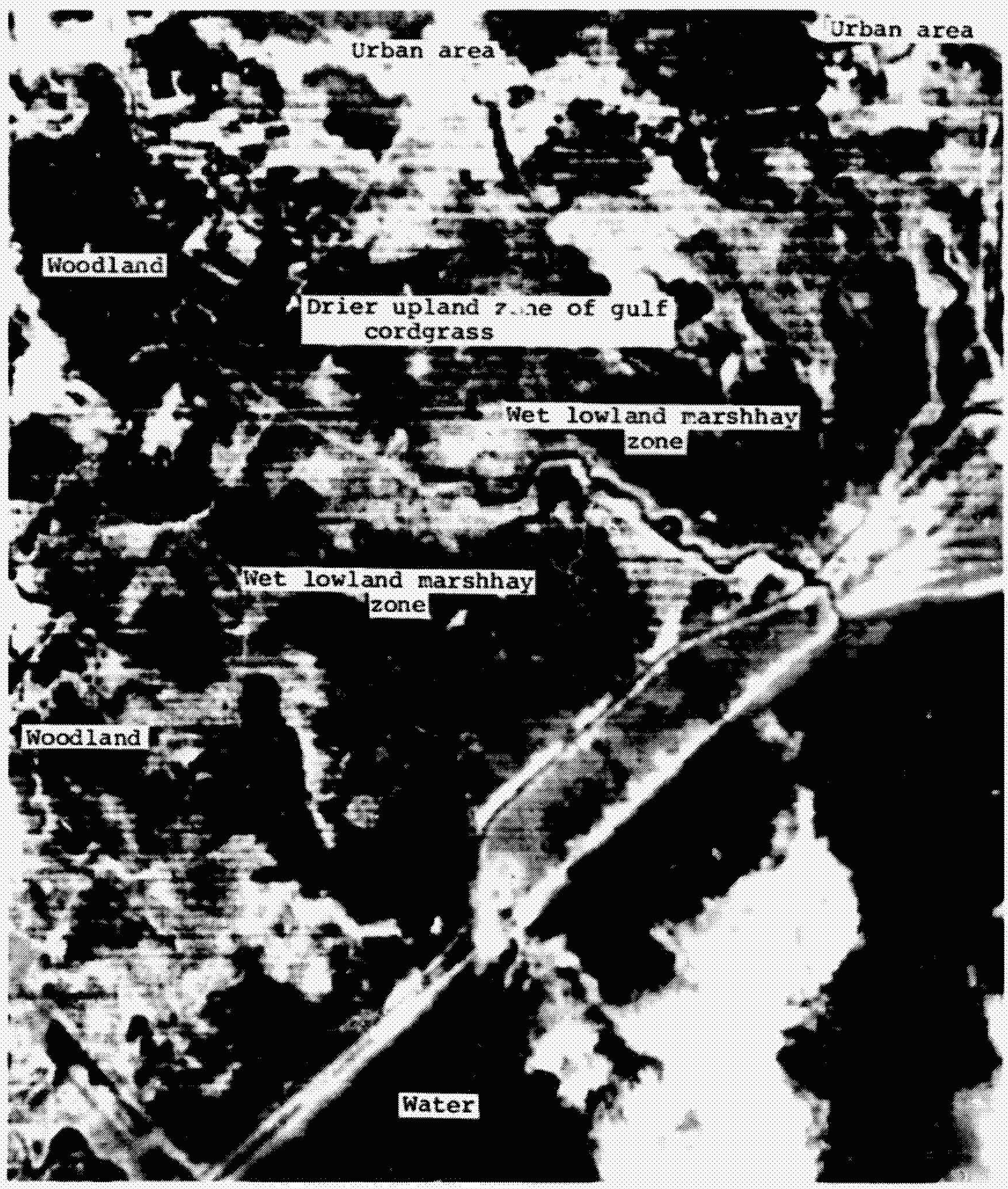

Figure 6-2.- Single-date, single-scene color enhancement of ERTS-1 October 4, 1972, film imagery of San Bernard site.

6.1.3 Areal Measurements and Regression Analysis

A total of 41 enhancements were produced from the Snook and San Bernard imagery. Of these, time limitations permitted only 11 to be interpreted and planimetered (figures H-1 through H-11). The planimetry was accomplished on a Dell Foster data quantizer. After the interpreted areas had been determined and tabulated by acreage measurement, data date, machine used, and the interpreter who created the enhancement, this information was analyzed in several ways. The average values from the three delineations by three interpreters are presented in tables 6-I and 6-II.

A regression analysis was one method used to evaluate the derived data. A linear model was chosen represented by the following equation:

$$Y = A + BX + E$$

where Y = areal measurement from ground-truth maps,

X = areal measurement from planimetering color enhancements of ERTS-1 film imagery,

A,B = coefficients to be estimated, and

E = error.

The coefficients A and B were estimated by inputting sets of measurements of X with the corresponding ground-truth measurements Y into a linear regression program on the Univac 1108 computer. A standard error figure ε of the closeness-of-fit of the prediction model

$$\hat{Y} = A + B\hat{X}$$

TABLE 6-I.- SNOOK SITE FIELD AREAL MEASUREMENTS PLANIMETERED FROM GROUND-TRUTH MAPS AND FROM COLOR ENHANCEMENTS OF ERTS-1 FILM IMAGERY

Field No.	Feature Type	Ground-Truth Measurement (hectares)	I^2S Measurements (hectares)				ACVP Measurements (hectares)			
			Aug 30	Nov 10	Dec 16	Temporal	Aug 30	Nov 10	Dec 16	Temporal
26	Nonwooded	12.1	23.9	8.9	-	-	20.6	-	93.1	-
24	Nonwooded	244.2	215.4	215.4	-	268.2	-	-	200.0	-
1	Nonwooded	6,003.5	5,827.1	6,525.0	-	-	4,777.9	-	6,630.6	5,485.7
7	Nonwooded	218.6	467.7	201.8	-	-	-	-	-	295.5
12	Nonwooded	167.2	-	83.3	-	-	121.1	-	114.8	150.2
8	Nonwooded	70.0	12.6	66.0	-	-	-	-	-	50.8
40	Nonwooded	44.1	30.4	52.5	-	44.1	42.5	-	21.5	42.6
30	Nonwooded	92.7	-	116.7	-	121.5	43.7	-	27.5	102.6
55	Nonwooded	721.5	-	692.0	-	-	1,020.6	-	-	1,266.1
16	Nonwooded	22.3	25.5	9.7	17.4	-	-	-	29.2	14.2
14	Nonwooded	61.5	53.6	34.8	31.6	55.8	92.8	-	55.3	73.6
1	Nonwooded	138.1	182.2	-	75.7	101.8	54.9	-	121.0	162.6
20	Nonwooded	153.1	-	-	34.3	139.3	125.3	-	122.5	132.5
5	Wooded	1,046.3	408.1	-	-	-	1,488.8	-	1,070.4	1,289.8
3	Wooded	166.8	155.1	83.3	-	110.4	-	-	188.9	166.3
4	Wooded	347.0	396.9	371.3	-	462.8	-	-	443.1	593.8
2	Wooded	404.1	114.2	-	-	334.9	347.8	-	-	376.2
29	Wooded	50.2	58.5	35.6	-	45.1	-	-	27.5	95.2
1	Wooded	9,072.7	8,994.2	14,858.5	-	5,428.8	8,911.0	-	-	-
100A	Wooded	164.0	222.7	206.4	-	175.1	249.7	-	-	-
7	Wooded	255.9	-	95.4	-	-	-	-	89.9	101.6
100B	Wooded	85.9	-	305.5	-	-	-	-	-	-
9	Wooded	17.9	-	51.7	-	6.9	-	-	56.6	25.9
13	Wooded	50.6	-	-	-	38.9	-	-	-	21.1
8	Wooded	87.5	-	80.2	-	-	72.1	-	82.2	81.4

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TABLE 6-II.- SAN BERNARD SITE FIELD AREAL MEASUREMENTS PLANIMETERED FROM GROUND-TRUTH MAPS AND FROM COLOR ENHANCEMENTS OF ERTS-1 FILM IMAGERY

Field No.	Feature Type[a]	Ground-Truth Measurement (hectares)	I^2S Measurements (hectares)		ACVP Measurements (hectares)	
			Oct 4	Nov 27	Oct 4	Nov 27
53A	GC	1,160.0	929.4	-	784.4	1,210.4
54	GC	563.6	544.3	506.7	544.6	401.9
53	GC	273.7	363.3	-	298.4	-
56	GC	68.8	69.6	-	-	-
53,73	TR	544.6	-	-	548.0	-
18,19	W	232.4	-	215.3	-	251.8
18A	W	28.3	-	19.8	-	21.5
19	W	40.1	-	19.4	-	-
59	W	12.1	-	32.5	-	-
59,60	W	26.3	-	25.6	-	32.0
45	W	39.7	-	-	-	41.0
1,2	W	27.5	30.4	-	38.1	-
15	W	100.8	113.7	116.4	245.8	91.1
6	B	14.6	-	16.3	11.7	13.4
44	B	301.2	384.1	-	-	-
2	T	35.2	60.1	-	-	24.1
10	T	14.2	14.6	-	-	-
16,17,44	MH	2,942.0	-	-	-	2,560.9
44,47,16	MH	2,918.1	-	2,792.3	-	-
10C	MH	2,957.0	2,719.7	-	3,731.7	-

[a]GC = gulf cordgrass, W = water, TR = transition (gulf cordgrass to marshhay cordgrass), T = wooded, B = burned gulf cordgrass, MH = marshhay cordgrass.

was obtained. The symbol ε is actually the statistical standard deviation of E. The prediction model states that future measurements obtained from planimetering a color enhancement under similar conditions as those in the range investigation will permit the true areal measurement to be predicted by $A + BX$ within an average error of ε.

Table 6-III presents the coefficients A, B of the regression models and the standard errors of the estimators for the cases when all features were considered, when only wooded rangeland was considered, and when only nonwooded rangeland was considered.

6.1.4 Discussion

The standard errors of the linear regression models were as high as 250 hectares (530 acres) when measuring areas as large as 10,500 hectares (22,500 acres).

The numerical figures in tables 6-I and 6-II indicate the large fluctuations in areal measurements across the enhancements from different dates and from different instruments. While rangeland features normally do not change substantially during a few months, such large fluctuations could be attributed to the fuzziness of the boundaries between the very complex range features. The inordinately large error figures were also believed to be due to the less-than-ideal quality of the color enhancements created in this investigation.

TABLE 6-III.- RESULTS OF LINEAR REGRESSION ANALYSES ON THE AREAL MEASUREMENTS OBTAINED BY PLANIMETERING COLOR ENHANCEMENTS OF ERTS-1 FILM IMAGERY

Site	Feature	A (acres)	B (dimensionless)	Standard error ε (acres)
Snook	All	8.0	1.03	430.5
	Woodland	39.2	1.04	529.6
	Non-Woodland	-0.9	1.00	311.3
San Bernard	All	62.8	0.96	513.0

Time did not allow further analysis into other sources of errors, the effects of the dates of the imagery, the instruments, and the various channel combinations. Higher-order regression models should also be examined.

6.2 COMPUTER PROCESSING

The results from supervised and nonsupervised classification are discussed and an overview of the results of these two types of computer-processing methods is presented. A typical classification map by supervised classification techniques and a typical classification-like clustering map by nonsupervised classification techniques are presented in figures 6-3 and 6-4.

6.2.1 Supervised Classification

Two sets of ERTS-1 MSS Snook data and two sets of San Bernard data were investigated: the Snook site data were acquired August 30 and November 28, 1972; the San Bernard data were acquired October 4 and November 27, 1972.

The two sets of Snook data were registered to each other on the ERIPS using Snook-1 as the reference scene. The sets then were composed to produce 8-channel data sets. The new data tape, Snook-1/2, comprised the first 4 channels of Snook-2. The same procedure was followed for the two San Bernard data sets. These two data tapes were then processed on the ERIPS, using 4 channels at a time for single-scene, single-date analyses, and all 8 channels for temporal analyses.

NASA S-73-28326

Color	Interpretation
green	Wet lowland zone of marshhay cordgrass
yellow	Drier upland zone of gulf cordgrass
brown	Wooded rangeland
blue	Water
off-pink	Urban area, bare soil

Figure 6-3.- Classification map of San Bernard site using supervised computer classification techniques (ERTS-1 October 4, 1972, digital data).

NASA S-73-28028

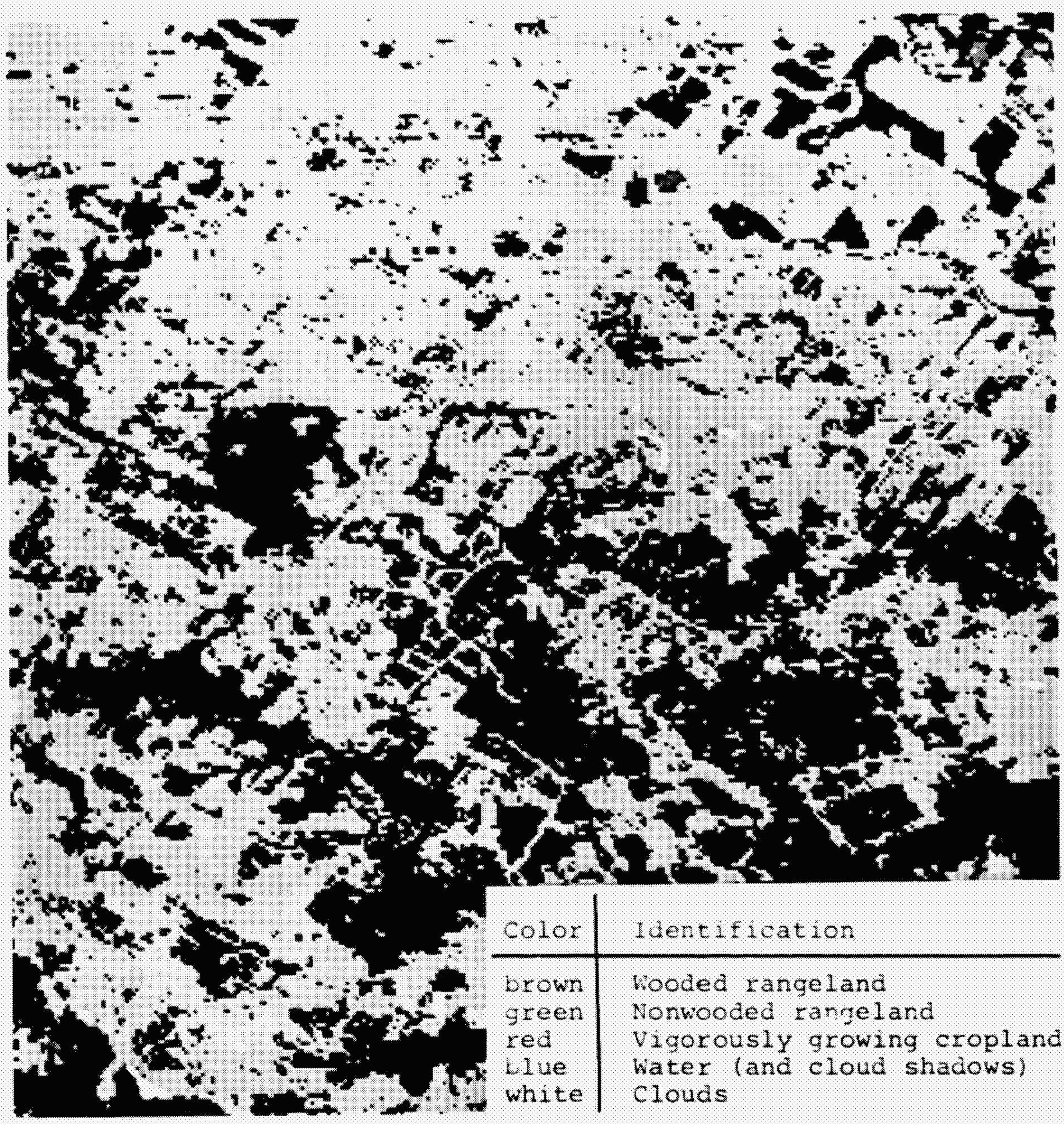


Figure 6-4.- Classification-like clustering map of Snook site using nonsupervised computer classification techniques (ERTS-1 August 30, 1972, digital data).

6.2.1.1 Results of single-scene, single-date processing.

6.2.1.1.1 Snook-1 and Snook-2: The same training fields and test fields were selected simultaneously for Snook-1 and Snook-2 by selecting them in the registered composed data set Snook-1/2. The coordinates of these fields applied to both dates and are tabulated in appendix F. The representative fields were (1) wet bottomland, (2) bermuda class A, (3) bermuda class B, (4) bottomland hardwoods, (5) mesquite, (6) dense oak stand, (7) sparse oak stand, (8) abandoned cropland class A, (9) abandoned cropland class B, and (10) water (Lake Somerville).

Using the standard LARSYS procedure, classification maps of Snook-1 and Snook-2 were produced (appendix I, figures I-1 and I-2). The training and test fields are also outlined in the color prints. Classification accuracies of the training fields and test fields are shown in tables I-I through I-IV in appendix I.

6.2.1.1.2 San Bernard-1 and San Bernard-2: Training fields and test fields were selected similarly for SB-1 and SB-2 (appendix G). These fields were representative of (1) deep-sea water, (2) coastal water, (3) inland lakes and turbid water, (4) marshhay cordgrass, (5) burned gulf cordgrass, (6) gulf cordgrass, (7) bare soil, (8) trees, and (9) smutgrass. Classifcation maps and tables of classification accuracy are found in figures I-3 and I-4 and tables I-V through I-VIII.

6.2.1.2 Results of temporal processing. The composed 8-channel data of Snook-1/2 and SB-1/2 were classified using the same training fields as in the single-scene, single-date processing. The classified imagery is shown in figures I-5 and I-6. The classification results are tabulated in tables I-IX through I-XII.

6.2.1.3 First-order classification. The first-order groupings of the 10 classes in the Snook data which were constructed resulted in four groups of features. The classes of bermuda A, bermuda B, abandoned cropland A, and abandoned cropland B were grouped into the category of open range; i.e., nonwooded rangeland. The classes of bottomland hardwood, mesquite, dense oak stands, and sparse oak stands were grouped into the category woodland. Bottomland and water remained separate categories.

These definitions for the Snook data permitted two more types of classification accuracy tables to be prepared. The first type was the first-order classification accuracy table of the training and test fields; i.e., the tabulation of fields in the four broad categories. The second type was the first-order classification accuracy table of training and test categories; i.e., the tabulation of training and test categories in the four broad categories. The Snook-1, Snook-2, and Snook-1/2 results are tabulated in tables I-XIII through I-XXV.

6.2.1.4 Summary of classification results. Bar charts were prepared to further summarize these classification accuracies (figures 6-5 through 6-8). The second-order

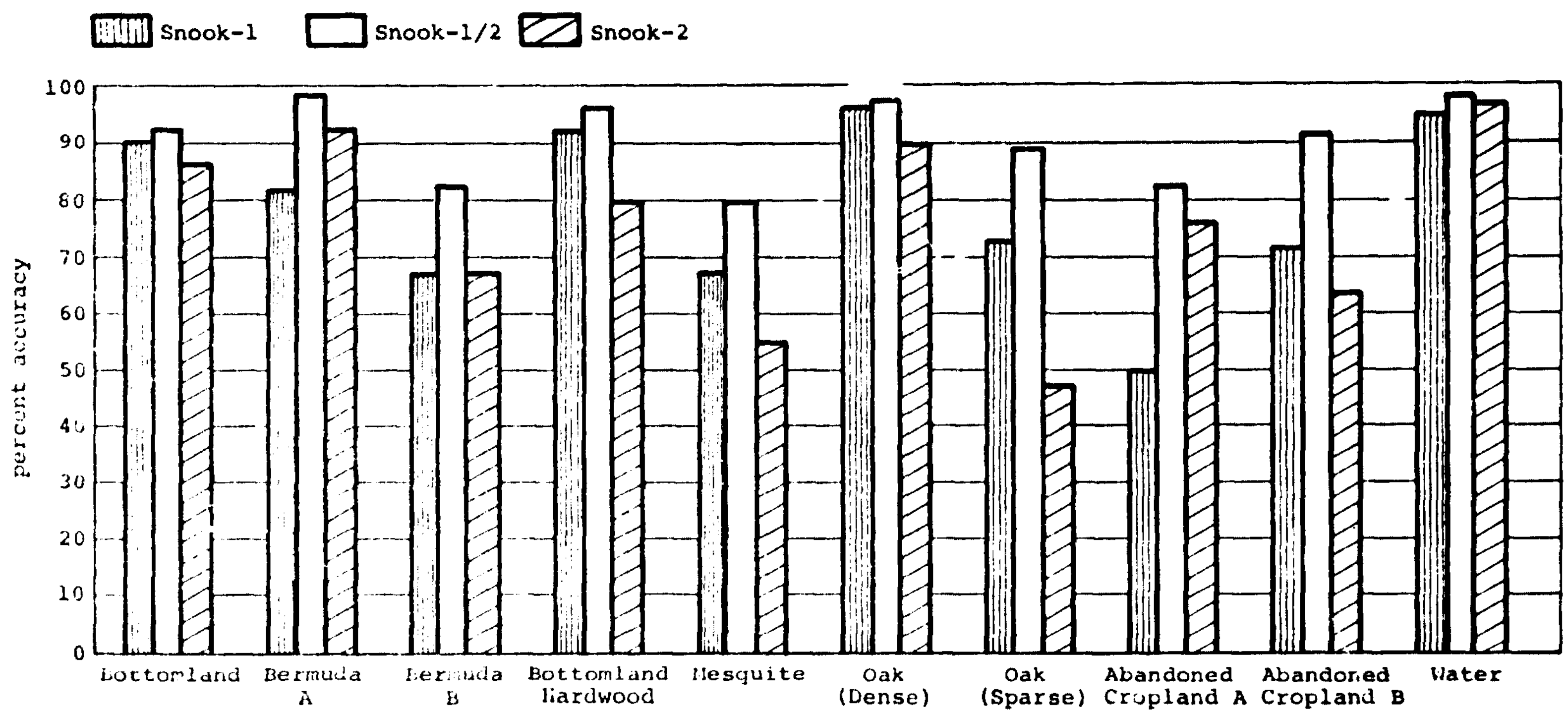
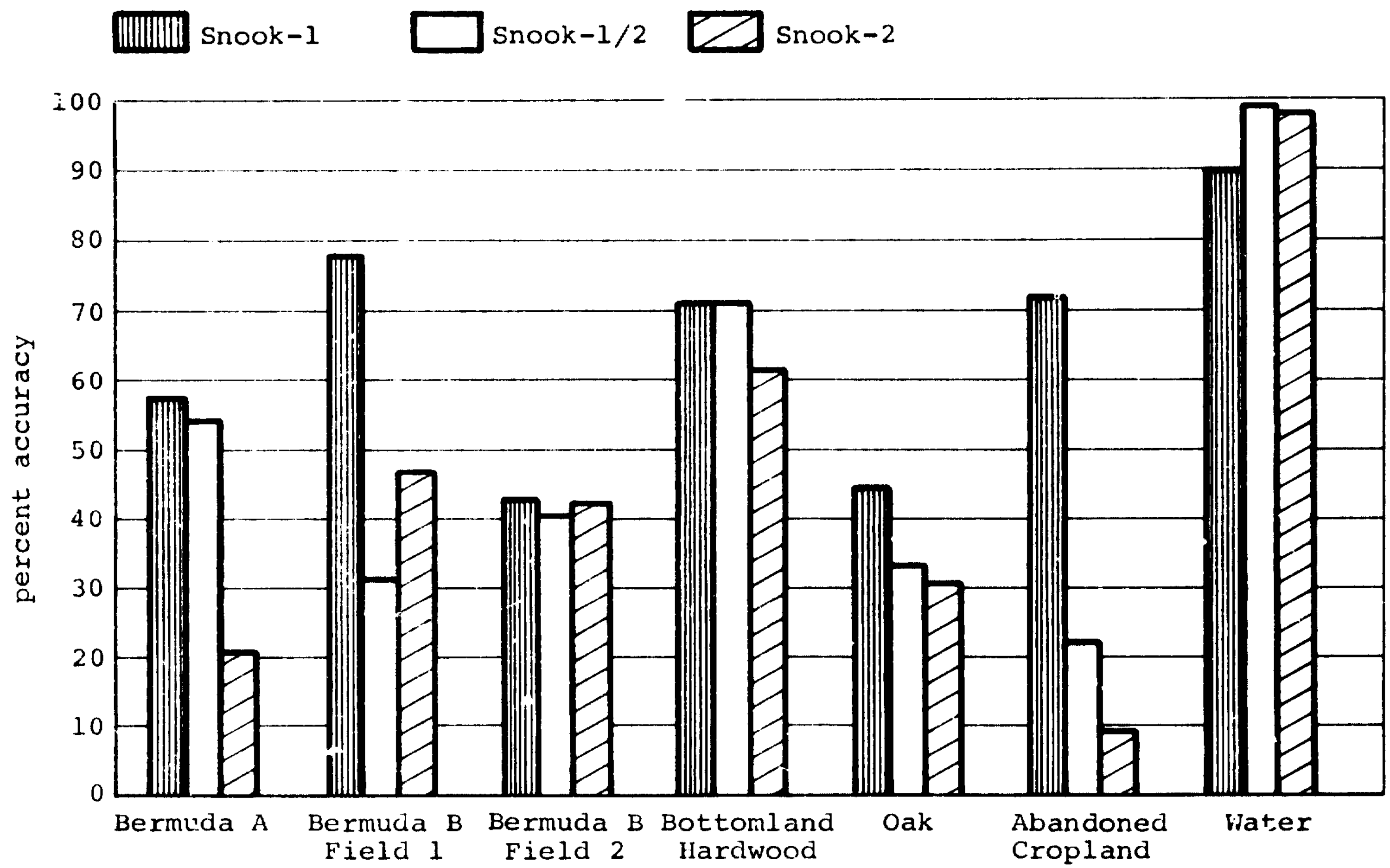


Figure 6-5.– Snook data second-order classification accuracy bar chart for training fields.



Field 6-6.– Snook data second-order classification accuracy bar chart for test fields.

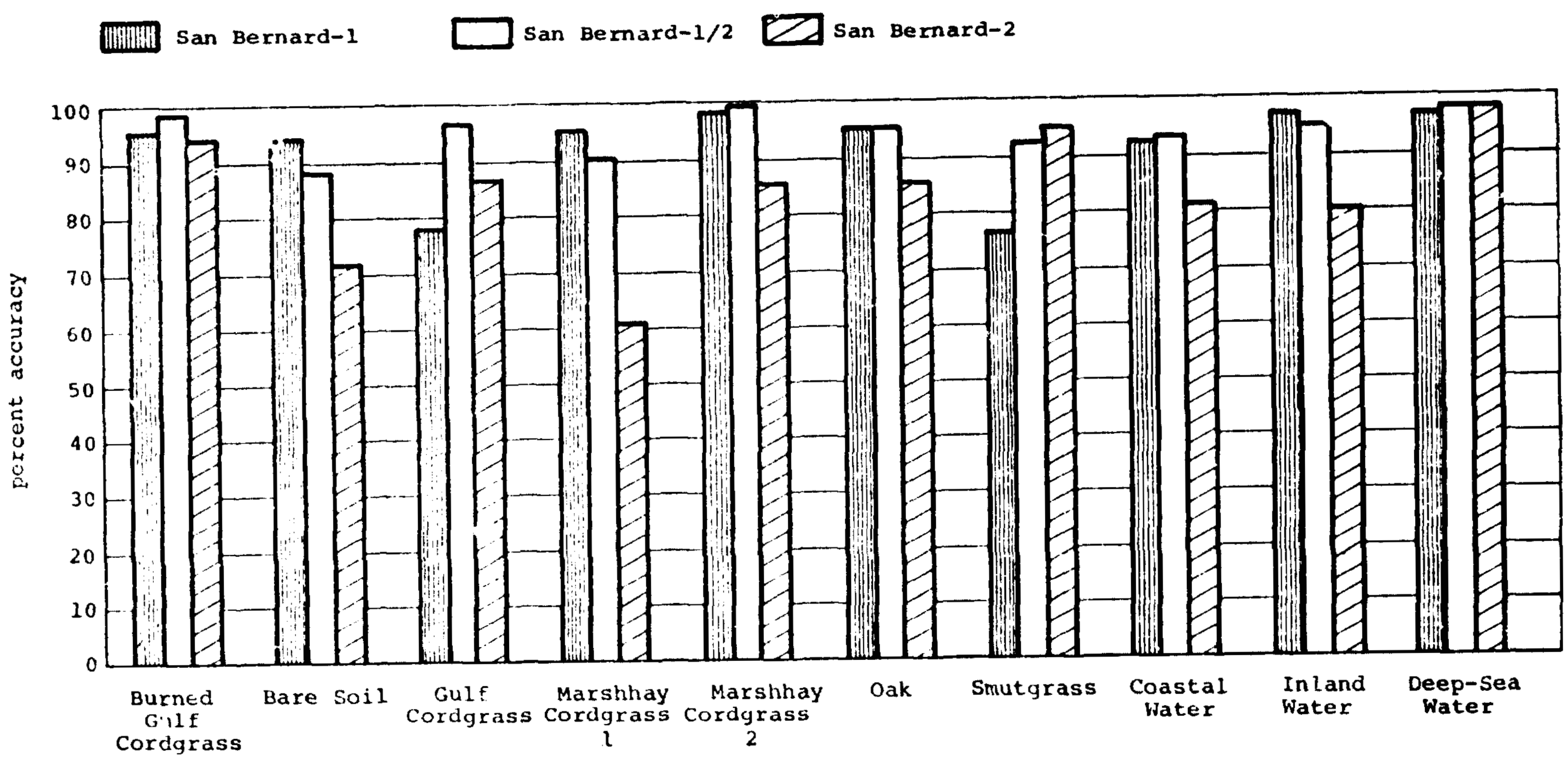


Figure 6-7.— San Bernard data second-order classification accuracy bar chart for training fields.

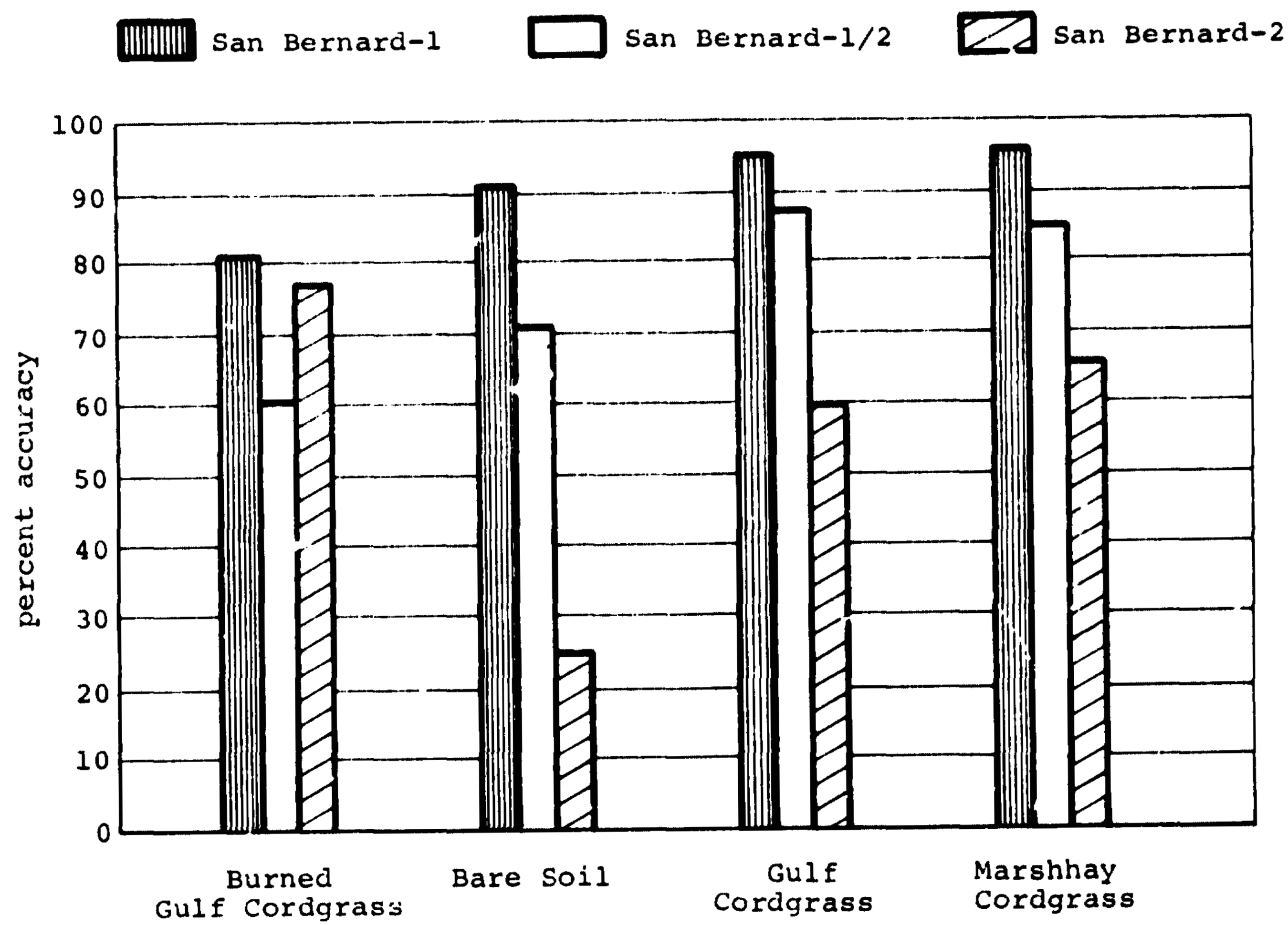


Figure 6-8.— San Bernard data second-order classification accuracy bar chart for test fields.

classification accuracies of the fields and classes for the single-scene, single-date data sets were plotted against the figures from the temporal studies. The overall classification accuracies (average classification accuracies) are plotted in figures 6-9 and 6-10.

6.2.1.4.1 Snook-1 training field classification: As shown in table I-I, the second-order classification accuracies for the training fields were fairly high. From tables I-XIII and I-XIV, first-order classification accuracies appeared even higher, with values as high as the mid-ninety percentile. The lower classification accuracies, such as those for mesquite (M) and sparse oak (P), may be explained by the natural similarity between these two classes and dense trees with grass understories. Table I-I indicates the classification of a number of data points in M and P into dense oak and bermuda fields, all were nonwooded types.

6.2.1.4.2 Snook-1 test field classification: Test field classification accuracies were generally poor (table I-II). This is believed due to the lack of adequate ground-truth information which resulted in training and test fields being selected which were not the same in all respects. In addition, various degrees of tree and grass mixtures in some of the categories accounted for low classification accuracies.

6.2.1.4.3 Snook-2 analysis: The same conclusions for the training field and test field classification accuracies were arrived at concerning the Snook-2 data. Note that the same training field for dense oak as for Snook-1 has 19 data points classified into bottomland hardware (table I-III),

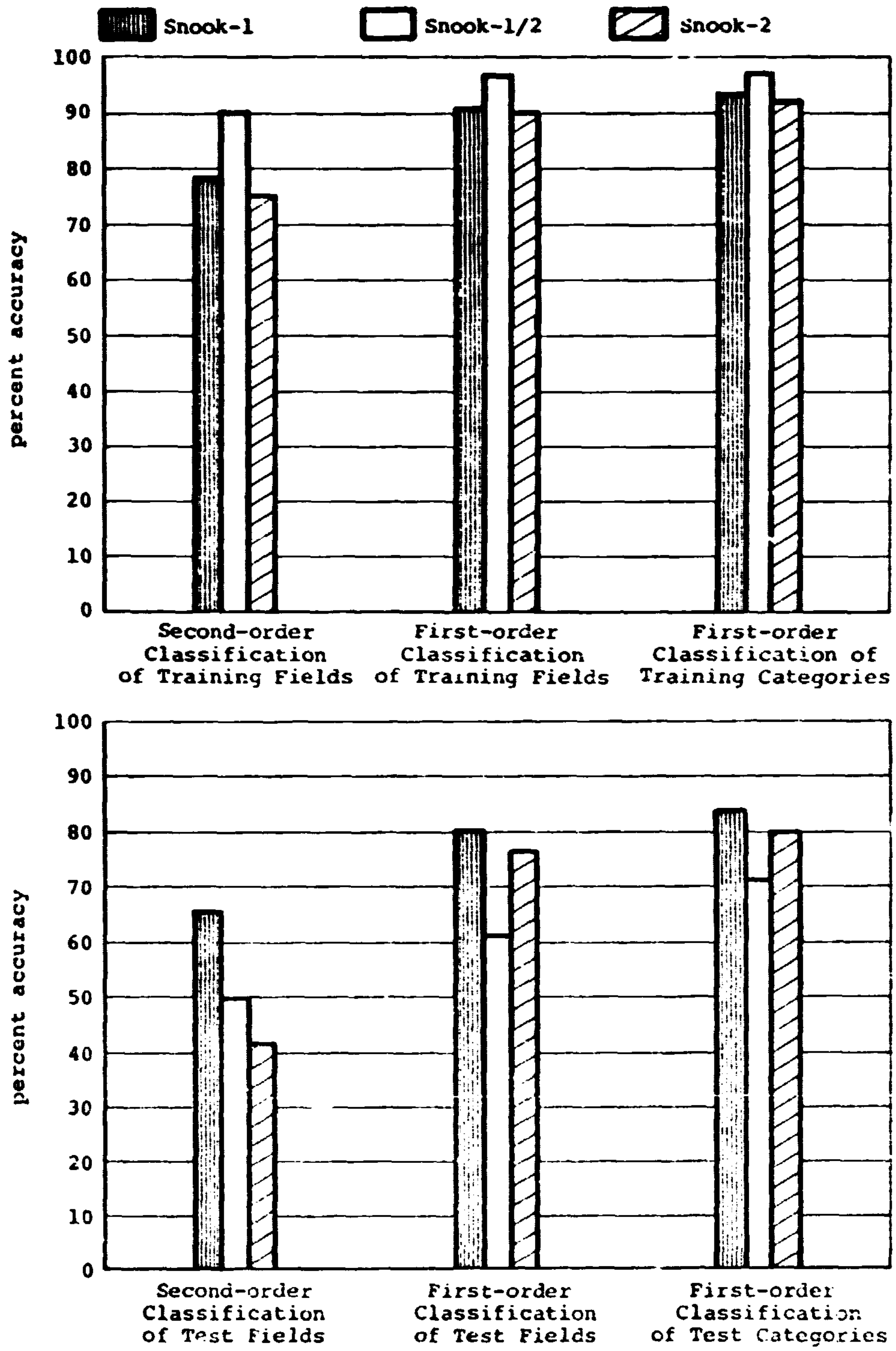


Figure 6-9.- Snook data overall classification accuracy.

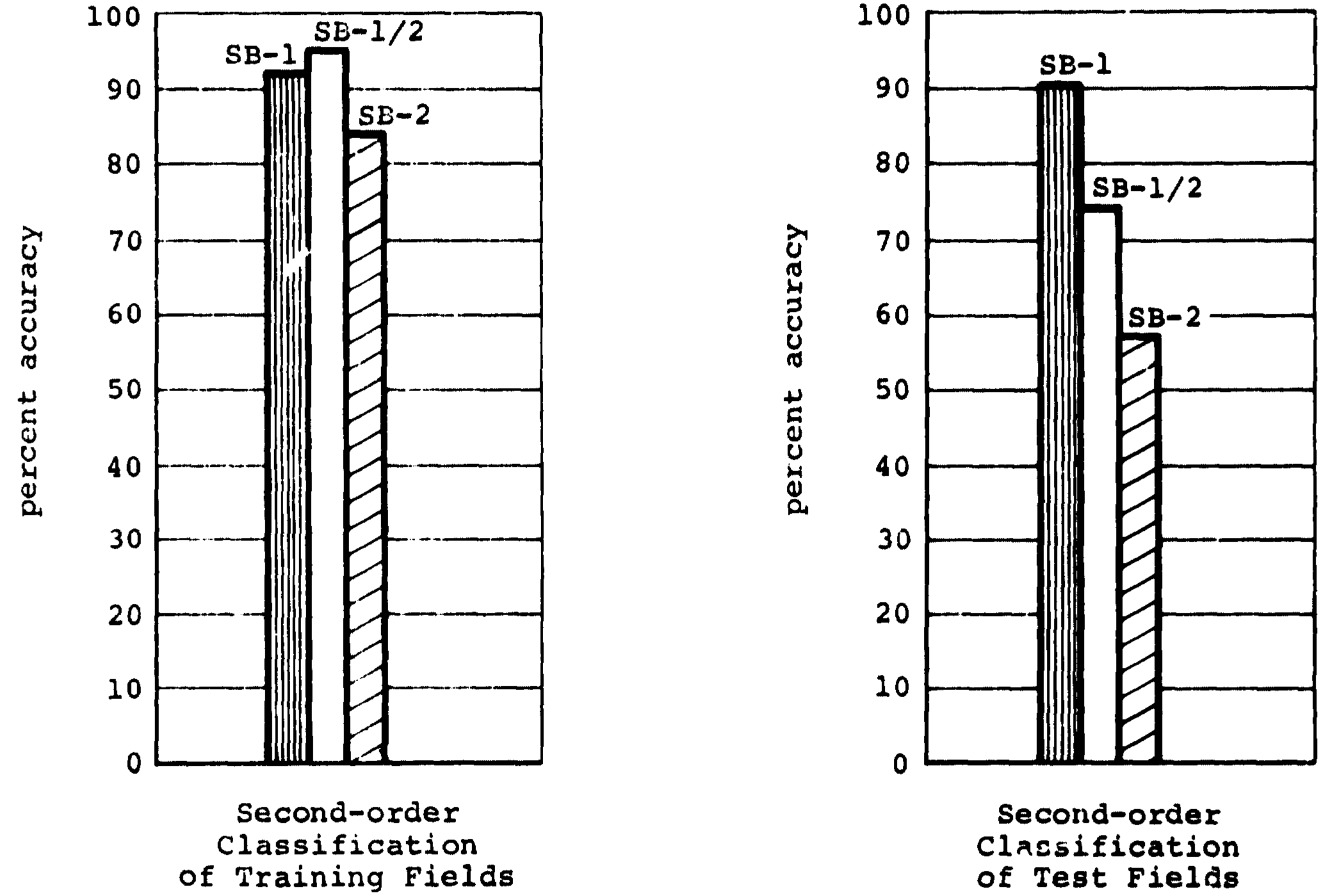


Figure 6-10.– San Bernard data overall classification accuracy.

while none were classified into hardware for the earlier Snook-l analysis. Similar confusion occurred between oak and hardwood in the classification figures for the category hardwood. Both results were probably caused by seasonal phenological changes that occurred in the vegetation between August and November, but which could not be described because of insufficient, continuing ground-truth data.

6.2.1.4.4 San Bernard analysis: The features of interest in the San Bernard site were quite well distinguished from one another. Classification accuracies were generally high (shown in tables I-V through I-VIII). In the SB-1 data, smut cordgrass and gulf cordgrass were confused with each other; less confusion occurred in the SB-2 data. This difference could again be explained by seasonal changes that occurred between the two dates.

6.2.1.5 Temporal analysis of training fields. The classification accuracies of the training fields of the two study sites were higher than the single-date, single-scene figures. This conclusion supports mathematical theory, which says that more discrimination exists between two statistical classes if more channels of independent information are used to describe the two classes. This trend is shown by the abundance of off-diagonal zero entries in classifications shown in tables I-IX through I-XII compared with tables I-I through I-VIII. The increase in classification accuracies was due to the increase in correctly classified data points which had been previously confused with other classes.

6.2.1.6 Temporal analysis of test fields. The addition of extra channels of independent information has shown that in the case of good training fields (where classification accuracies were higher than approximately 80 percent), discrimination between features was higher in temporal analyses than in single-date analyses. In other words, a data point which belonged to class 1 and which was confused as belonging to class 2 in a single-date analysis, even though it was not unrepresentative of class 1, would probably be classified correctly as class 1 in a temporal analysis. On the other hand, a data point of class 1 which was not very characteristic of class 1 but which was still classified in class 1 during a single-date analysis would likely be thresholded out (not classified in) class 1 during a temporal analysis. This induction was verified by the temporal analysis results of the available test fields. Good test fields (classification accuracies above approximately 80 percent) had higher classification accuracies, while bad test fields had lower classification accuracies in temporal studies compared with single-date studies.

6.2.2 Nonsupervised Classification

Nonsupervised classification is the grouping of multispectral data into spectrally homogeneous groups without computer training. A few parameters in ISOCLS can be input by the user which affect the mode of operation. The three parameters of particular interest are STDMAX, DLMIN, and MAXCLS.

In program ISOCLS, a class (cluster) is considered to be a union of subclasses (subclusters) of nominal sizes.

The size of a nominal-size cluster is governed by STDMAX (maximum standard deviation). A cluster of a standard deviation larger than STDMAX in any one of the channels would be divided into two subclusters. And if two clusters are spectrally similar and have a measure of similarity smaller than DLMIN (minimum distance), the two clusters are combined. The MAXCLS (maximum classes) parameter determines the maximum number of clusters generated by the program. The four different approaches discussed in the following sections were exercised on Snook-1 data and the results are presented in section 6.2.2.2. Nonsupervised classification results on Snook-2, San Bernard-1, and San Bernard-2 are presented in section 6.2.2.3. Since no CCT compatible to the UNIVAC 1108 computer was available on the temporal Snook-1/2 and San Bernard-1/2 data and since the clustering program on ERIPS was not operational at the time of this investigation, nonsupervised temporal analysis was not performed.

6.2.2.1 Four approaches to classification. In the first method, Program ISOCLS generated the necessary nominal-sized subclusters, and similar subclusters were combined automatically by the DLMIN criterion. This was achieved by setting MAXCLS to a large value, setting DLMIN to 3.2 (a value suggested in reference 4) in regard to the probability of misclassification, and setting STDMAX to values between 2.5 to 3.5 (for the ERTS-1 data which require discrete values from 0 to 127). This procedure produced an approximate second-order classification.

In the second method, Program ISOCLS grouped the data into a predetermined number of spectrally similar groups

(MAXCLS). The DLMIN was set to zero and STDMX was set to 4.5, which produced a coarser grouping than the previous method. Depending upon the potential number of classes and subclasses present in the data set, limiting MAXCLS to a small value yielded a coarse second-order or first-order classification.

In the third method, the results obtained in the second method were manipulated so that spectrally similar groups were grouped together. Clusters separated by a distance less than 3.2 were grouped together either automatically in the "chaining process" of the program, or manually during display of the output result. This produced an approximate first-order classification based on spectral similarity.

In the fourth method, the results of ISOCLS clustering obtained in either method 1 or 2 were initially interpreted. Then, clusters that corresponded to classes of the same or similar vegetation types were grouped together to produce a first-order classification.

6.2.2.2 Snook-1 analysis. Five classification maps of the Snook-1 data are discussed.

Figure J-1 in appendix J is the result obtained by clustering Snook-1 data according to the first approach discussed in the preceding section. Only 10 of the 25 clusters obtained were considered major because of the noise and clouds present in the data. The interpretation of these clusters is found in table J-I.

Figures J-2 and J-3 are the results of using the second approach discussed in section 6.2.2.1. The computer run corresponding to figure J-2 had MAXCLS set equal to 5, and the run corresponding to figure J-3 had MAXCLS equal to 8. The interpretation of these clusters is found in tables J-II and J-III.

The results of the computer run corresponding to figure J-2 were manipulated as discussed in approach 3 of section 6.2.2.1 to yield figure J-4, a three-class classification map. The three classes were interpreted as vigorously growing cropland (red), water (blue), and other, which included rangeland of all vegetation types (yellow).

The results of the computer run corresponding to figure J-3 were manipulated as discussed in approach 4 of section 6.2.2.1. This gave the first-order classification of figure J-5, where five classes are distinguished as vigorously growing cropland (red), water (blue), clouds (white), wooded rangeland (brown), and other, nonwooded rangeland (yellow).

6.2.2.3 Other analyses. The same approaches were applied to obtain second-order classifications of Snook-2, San Bernard-1, and San Bernard-2. The classification maps and cluster interpretations are shown in figures J-6, J-7, J-8, and in tables J-IV, J-V, and J-VI.

6.2.2.4 Discussion on clustering results. From theoretical considerations and past experience with ISOCLS, different clustering results would normally be expected when different parameter values were input to the program.

In all cases, the user should interpret the cluster results considering the parameter values used. With regard to the possible ways to exercise the ISOCLS program and the corresponding interpretation of the results, four approaches were discussed in sections 6.2.2.1 and 6.2.2.2. Nonetheless, the identification of the clusters remains as a tedious and difficult task.

Upon examining the cluster results of the Snook-1 and Snook-2 data, the Snook-2 data generally had much lower reflecting radiance levels than Snook-1 data. In fact, the radiance levels were almost halved in the Snook-2 data compared to the Snook-1 data. This difference was believed mainly due to the seasonal changes in the Sun angle and the advancement in the life cycle of the various vegetation in the scene. Whatever their causes, these level differences made comparing the two results difficult, since no attempt was made to accommodate these effects. The same phenomenon occurred in the SB-1 and SB-2 data.

Because the clustering process is rather time-consuming, a sampling approach was deemed desirable if the clustering results would not be severely affected. The savings in computation using a sampling scheme were obvious because in a sampling scheme where lines and picture elements (pixels) are skipped, essentially a smaller amount of data were analyzed. To test this, the computer run corresponding to figure J-3 was actually repeated with every third, every fifth, and every tenth line and pixel under the same running conditions as in the case of no sampling. The cluster centers of the four runs (tabulated in table 6-IV) agree closely. This suggests that the sampling technique is indeed a viable approach to reduce computation time.

TABLE 6-IV.- COMPARISON OF CLUSTER CENTERS OBTAINED FROM CLUSTERING RUNS WITH VARIOUS SAMPLING SCHEMES

Sampling Scheme: Scheme 1: no sampling; Scheme 2: every third line and pixel; Scheme 3: every fifth line and pixel; Scheme 4: every tenth line and pixel

Cluster Interpretation	Sampling Scheme	Clouds	Woods	Wet Bottomland, Wetland	Water	Grassland, Sparse, Dry	Healthy Vigorous Agricultural Fields	Open Range, Grassland, Bermuda	Not So Vigorous Agricultural Fields, Grassland
Channel 1	1	66.3	29.9	34.4	28.0	38.3	32.0	33.2	32.8
	2	64.1	29.7	34.8	29.5	39.0	32.5	31.5	33.3
	3	59.9	29.7	34.8	27.6	38.5	32.0	31.6	32.9
	4	54.3	30.5	35.6	27.7	34.7	32.0	32.3	33.7
Channel 2	1	65.7	21.7	29.8	17.9	35.4	22.3	26.6	24.6
	2	61.6	21.7	29.7	20.8	36.8	22.5	24.4	25.0
	3	56.7	21.6	29.5	17.5	35.1	21.9	24.0	24.7
	4	54.4	22.5	31.1	17.1	29.1	22.1	24.5	26.0
Channel 3	1	70.4	37.0	33.8	11.8	47.4	72.5	43.0	52.6
	2	69.3	36.4	42.3	13.6	47.8	72.8	41.9	51.5
	3	64.9	35.3	41.1	11.4	48.4	71.8	40.9	51.2
	4	58.6	37.9	34.5	8.6	44.1	71.0	25.1	52.1
Channel 4	1	33.6	20.5	18.2	5.5	24.5	40.5	23.0	29.3
	2	32.5	19.8	22.1	10.[illegible]	24.3	38.4	22.4	28.7
	3	31.2	19.7	21.8	4.4	25.0	41.5	22.2	28.4
	4	29.6	21.1	19.2	4.1	23.5	40.5	17.0	28.5

6.2.3 General Discussion

6.2.3.1 Supervised classification. The present LARSYS-type classification technique is the best technique available with the existing state-of-the-art, but requires the assumptions that (a) the training fields have Gaussian statistical distributions, and (b) the user desires to best classify the unknown data into one of the available training categories; i.e., to identify the spectral similarity or dissimilarity between the unknown data and the known categories. If a training field consists of only bermuda grass at a praticular growth stage under certain soil and climatic conditions, a LARSYS classification only identifies bermuda fields and non-bermuda fields in the unknown data which are spectrally similar to the bermuda training field. Obviously, bermuda fields under other conditions and other fields with the same spectral characteristics as the bermuda training field would be classified as bermuda. This result is not the fault of the procedure. Rather, it is due to the lack of discrete spectral distinction within as well as between various vegetation types. If the user wishes to classify all the bermuda fields which exist in the unknown data, he needs to know all the subclasses of bermuda fields in the data. Then he must program the computer to recognize all these subclasses, a very difficult if not impossible task. Furthermore, the user must devise a way to recognize the fields that are classified as bermuda, but which really are not bermuda fields. This latter requirement is still without a solution.

6.2.3.2 Nonsupervised classification. To compensate for the lack of complete training information, nonsupervised

classification is an alternative approach because without previous information, the technique groups the unknown data into spectrally homogeneous clusters. Although an identification of these clusters would then lead to a classification map, the process is tedious and often difficult. Also, as discussed in section 6.2.2, the clustering results depend on the choice of values of the various input parameters. Several ways of judiciously exercising the program and subsequent interpretation of the results were presented.

6.2.3.3 Temporal analysis. The bar charts of figures 6-5 through 6-10 illustrate the verification of the mathematical theory that discrimination between features becomes higher in temporal analyses than in single-date analyses. This was possible by adding extra channels of independent information and the description of a feature by a temporal signature. The advantage of temporal analyses over single-date analyses is obvious from the example of deciduous trees. Numerous features appear light green in spring, many appear richly green in summer, dozens appear yellow in autumn, and scores appear brown in winter. However, the 1-year behavior of a feature that appears light green in spring, richly green in summer, yellow in autumn, and brown in winter, suggests that the feature is a deciduous tree.

6.2.3.4 Test fields versus training fields. The limited amount of ground truth available made defining enough training fields almost impossible. The same limitation also prevented test fields being chosen that belonged only to the same general category as the training fields. Subsequently, the classification accuracies of test fields in this investigation were not high. Future studies using

satellite data should acquire more intensive ground truth so that test fields and training fields can be chosen of the same classes and subclasses.

6.2.3.5 Refinement of training fields. As suggested earlier, training classes should be studied for their homogeneity, especially when more than one field of the same training class is selected. This is to determine whether subclasses should be defined. However, as mentioned previously, such definitions require much more intensive ground information than was available in this investigation.

6.2.3.6 Quantitative analysis and comparison. Quantitative analysis and comparison were not made between the results of different cluster runs or between the results of the supervised and nonsupervised classification. The main reasons were: (1) The JSC capability was not available in time to obtain undistorted classification maps and thereby to make areal measurement, comparison, and analysis; (2) no attempt was made to accommodate the variation in data values in the data sets of different dates; (3) time did not permit further in-depth visual comparison between the various classification results; and, (4) the statistics of the training fields defined in the supervised classification processes were accidentally lost, which prevented a comparison with the cluster statistics of the nonsupervised classifications.

6.3 SUMMARY AND SUGGESTIONS

6.3.1 Summary of Work

Five ERTS-1 MSS film imagery data sets and four ERTS-1 MSS digital tape data sets were investigated and discussed.

Eleven color enhancements were created and interpreted using conventional photointerpretation techniques. Six classification maps and eight classification-like cluster maps were obtained using computer data-processing techniques.

6.3.1.1 Output products.

a. Conventional Data Processing

1. Single-date enhancements of the August 30, November 10, and December 16 Snook data.
2. Multidate enhancements of the temporal Snook scene composed of data of the same three dates as (1).
3. Single-date enhancements of the October 4 and November 27 San Bernard data.
4. Multidate enhancements of the temporal San Bernard scene composed of data of the same two dates as (3).

b. Computer Data Processing

1. Classification and cluster maps of the August 30 and November 28 Snook data.
2. Classification maps of the temporal Snook scene composed of data of the same dates as (1).
3. Classification and cluster maps of the October 4 and November 27 San Bernard data.
4. Classification maps of the temporal San Bernard scene composed of data of the same dates as (3).

6.3.1.2 Analysis work on output products.

a. Conventional Data Processing

The 11 color enhancements were delineated, interpreted, and planimetered. The delineation and interpretation were performed by three persons unfamiliar with the study site and not associated with the Range Analysis Team. Planimetering of each delineated area was performed three times and the results were averaged. The areal measurement figures obtained were tabulated and analyzed through a linear regression analysis. The output products and their analyses are discussed in sections 6.1.1 and 6.1.2.

b. Computer Data Processing

The classification results were tabulated and manipulated to obtain the first-order and second-order classification accuracies. The clusters in the classification-like cluster maps were interpreted and also tabulated. The output products and their analyses are disucssed in sections 6.2.1.4, 6.2.2.4, and 6.2.3.

6.3.2 Suggested Improved Methods

a. Acquire Intensive Ground Truth

Information on the growth stage, soil moisture, climatic condition, and past history, were necessary in the analysis and also for defining accurate test areas versus training areas. The failure to collect this type of information would prevent comprehensive quantitative analyses and comparisons. Also, aircraft data should be acquired concurrently with ERTS-1 coverage to construct accurate controlled ground-truth information.

b. Remove Distortion From Computer Products

Image-to-ground registration of the ERTS-1 processed products and registration to larger-scale imagery used as ground truth should be performed. This will remove the inherent distortion that exists in the ERTS-1 products and would permit areal measurements amenable to comparison with ground-truth information. Additional comprehensive quantitative analyses could then be performed.

c. Atmospheric Correction and Signature Extension

The seasonal migration of the Sun causes variations in the reflecting radiance levels of even the same features over a period of time. Removing such an effect or even transforming to obtain the absolute reflectivities of features would permit a meaningful comparison between different computer classification and clustering results of data sets of different dates. Correction of other atmospheric effects such as haze would allow the extension of spectral characteristics or signatures and could possibly lead to a signature bank of various features.

d. Further Regression Analysis

Instead of simply using a linear model, higher-order regression models should be considered for analysis of the planimetric measurements from the delineated color enhancements. Also, additional methods need to be evaluated to provide reliable inferences from the statistical data being investigated, as well as for the prediction model obtained. Additional analyses are necessary regarding partitioning of the variance about regression, and the use of dummy variables to asborb effects such as machine (I^2S or Itek), data dates, interpreters, and wavelength bands.

e. Emphasize Temporal Analysis

The limited experience gained in this investigation indicated the advantages of temporal analyses o r single-date analyses, and future studies should attempt more temporal analyses. The time span of temporal data sets should be extended from 2 or 3 months to perhaps even 1 year. Nonsupervised classification of temporal data sets should also be attempted.

7.0 CONCLUSIONS

The ERTS-1 Range Analysis Team studied two areas in the Houston Area Test Site in a 1-year investigation to determine the utility of ERTS-1 remote sensor data for vegetation type-mapping of range and related grazing land. At least two sets of data (two dates of the same scene) of the study areas were investigated for the purpose of temporal analyses. Conventional photointerpretation techniques, as well as computer data processing techniques, were used for processing MSS film and digital tape data. The following conclusions were drawn.

7.1 CONVENTIONAL DATA PROCESSING

a. Examination of the color enhancements created on the film viewers indicated that first-order classification of both sites was satisfactory. Each site was successfully separated into wooded rangeland, nonwooded open rangelend, cropland, water, and urban area (section 6.1.2).

b. Separation of the wet lowland zone of marshhay cordgrass from the drier upland zone of gulf cordgrass in the San Bernard site was achieved. These were second-order features (section 6.1.2).

c. Regression analyses were conducted to correlate the areas interpreted from color enhancements against ground truth. A linear model was developed that would predict the true areal measurement from a measurement obtained from a color enhancement created on the available film viewers. However, the standard errors of the areal measurements were as high as 250 hectares (530 acres) when areas

as large as 10,500 hectares (22,500 acres) were measured. The inordinately large error figures were believed to be due to the fuzziness in boundaries between the extremely complex vegetation zones, and also to the less-than-ideal quality of the color enhancements created in this investigation (section 6.1.4).

d. Some features, such as cropland, were enhanced and accented from the background more vividly in the temporal enhancements than in the single-date enhancements (section 6.1.2).

7.2 COMPUTER DATA PROCESSING

a. Classification accuracies of training fields were high. By aggregating the second-order fields into first-order categories, the first-order classification accuracies appeared even higher, with values as high as the mid-ninety percentile (section 6.2.1.4).

b. Temporal analyses gave even better classification accuracies for the training data. Furthermore, confusion between training classes was reduced (sections 6.2.1.5 and 6.2.3.3).

c. Classification accuracies of test fields were not as high as those of training fields. Again, the first-order classification accuracies appeared higher than second-order classification accuracies. The choice of nonrepresentative test fields was believed to be due to the lack of intensive ground truth and the insufficiency in the number of spot-checked fields (section 6.2.1.4).

d. First-order classification was generally satisfactory for both sites; i.e., separation into wooded rangeland, nonwooded rangeland, cropland, and water. In the San

Bernard site, the soil moisture content in the marshhay cordgrass and that in the gulf cordgrass were sufficiently different to permit separation between the two classes (section 6.2.1.5).

e. Clustering results were very useful. This was because no training information was required to identify spectrally homogeneous areas in the data. Further still, this nonsupervised classification technique allowed the grouping of unknown and/or even subtle features into spectrally unique groups which further analysis could perhaps assign significance. An attempt to use a sampling technique to reduce the computation time of the clustering process was also made, resulting in positive conclusions (section 6.2.2.4).

f. Clustering results appeared to be very satisfactory for first-order classification, and to a certain extent, for second-order classification. A quantitative analysis of the classification accuracies was not made due to a lack of intensive ground truth (section 6.2.2.4).

7.3 OBSERVATIONS

An attempt to objectively compare the two classes of data processing methods was not made. However, from the experience gained in this investigation, computer processing methods seem to be more amenable to systematic quantitative analysis. This is to be expected when the delineation and interpretation of color enhancements is a tedious and often difficult task. The results of this investigation showed that planimetric results fluctuated considerably, the reason for this being attributed to the fuzziness of boundaries between the extremely complex features.

Finally, it is suggested that future investigators should entertain the idea of a possible redefinition of the terminologies of features or even the objectives of similar studies. From the results of this project, second-order features, as defined in the project prior to the actual investigation, were often confused with one another, except in cases where the soil moisture content in the features was vastly different. This fact suggests that perhaps features should be defined in terms of their soil moisture content and other factors, such as bare soil and land, and foliage cover or trees because the ERTS-1 satellite senses all data as a mixture of features. Perhaps the detection of features should be viewed in a different way as the detection of these factors in the features.

Three positive findings are summarized from this effort:

1. The Range Analysis Team demonstrated the utility of of ERTS-1 MSS data to map vegetation types satisfactorily into first-order broad categories. Rangeland comprising woodland and nonwoodland was distinguished from nonrangeland comprising water, urban area, and cropland.
2. Second-order finer classification was also possible, depending on the existence of certain not yet fully understood characteristics in the features, such as soil moisture content. The demonstration of the ability to separate the wet lowland zone from the drier upland zone; e.g., in the San Bernard site, should be of significant value to users interested in mapping wetland features in coastal areas.

3. Temporal Analysis, particularly using computer-aided techniques in processing digital data, enhanced the discrimination between nearly all vegetation types in this investigation. This conclusion supports the prediction from mathematical theories.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, January 24, 1974
641-14-07-50-72

8.0 REFERENCES

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APPENDIX A
WHAT IS RANGELAND

Traditionally, rangeland has been associated with the primary use of domestic livestock grazing. Although this is only one of many uses of rangeland, for the moment, consider it as the only use, and attempt to define rangeland, based on the production of forage. Although not entirely accurate, assume for the present that cattle eat grass only. Then the definition of rangeland must be simple grassland. Immediately, however, the problem of defining grassland arises, because virtually all the vegetated surface of the earth has grasses on it, and most, if not all, is potential grazing land. Therefore, the equating of rangeland to plains and prairies is not sufficient.

Another criterion which could be used to define rangeland is historical use. And from the standpoint of livestock production, it is probably a fairly good standard to use. If past use is chosen as the criterion, however, virtually all the area of the 50 United States must necessarily be included, with the exception of some of the true desert regions of the Southwest. There is little doubt that any area even poorly suited to domestic livestock grazing has not been so used. Note that this definition includes vast areas of wooded land, brushland, grassland, and every combination of all three. Even today, over 40 percent of the land area of the 50 states is grazed by livestock (U.S. Department of Agriculture, 1962). Now a definition of rangeland is possible because it is accurate, if not unique. Range was defined by the Society for Range Management as "all land producing native forage for (wild

or domestic) animal consumption. . . ." (ref. 7). Thus, range is virtually all-inclusive ecologically, and that fact must be recognized if practical remote sensing applications for range management are to be developed.

Although it was assumed in the foregoing discussion that grazing was the only use of rangeland, this concept must be discarded if the management of rangeland is considered in a modern context. No longer can any federal agency view grazing as the only use, or even the best use, *a priori*, for any piece of land. Indeed, any grazing on public lands is a current point of controversy, if not ecologically, at least politically (ref 8).

If consideration is restricted to private rangeland, as in virtually all the State of Texas, then of course grazing might be defined as the only use. The use of private land is the responsibility of the land owner, regardless of what the "best" public benefit may be, at least for the present. Of more importance to the nation is the administration of public rangeland, since it can be used in a manner responsive to the needs of the country. Besides grazing, other uses of public land which must be considered include watershed, wildlife, timber and pulpwood, and numerous forms of recreation.

To summarize the foregoing discussion, it is seen that (a) rangeland is not an ecologically unique type of land, (b) grazing is not necessarily the only or best use of rangeland, and (c) modern resource management practices demand many other usages of rangeland, the best utilization of which is of keen interest to mankind.

APPENDIX B

CREATING COLOR ENHANCEMENTS ON THE I^2S MODEL 2000 MCFV

1. Rationale – The rationale behind the operation of the I^2S Multichannel Film Viewer (MCFV) is to create color enhancements which tend to 'pull out' those features of interest from the rest of the scene. This means contrast in colors between features of interest and features of no interest. Unless it is the case of a pure black and pure white duo-shade enhancement of a two-class classification, the degree of contrast and thus, the degree of success is rather subjective. Furthermore, enhancements are analyzed by human interpreters, who, by definition, are individuals and are thus subjective. Therefore, considering the extreme versatility of the MCFV, it is obvious that no step-by-step operational procedure can be set. Rather, some normal procedures to approach the problem are presented in the following paragraphs.

2. Preparation of Data – The I^2S Model 2000 MCFV is an electro-optical instrument designed to accept three channels of black-and-white positive or negative multiband camera film transparencies. The scanner film gates accept roll film of up to 5-inch width or cut film chips. Since the bulk MSS ERTS-1 data are in 9-1/2 inch or 70-mm formats, appropriate cutting and preparation of film chips are sometimes necessary.

3. Registration of Data – To fully utilize the capability of the MCFV, three channels are normally used simultaneously. The films previously prepared and mounted on the

film transports are registered by adjusting the translation, rotational and expansion (z-axis) controls. This is achieved by first fixing one channel of data as the reference channel. Then, the other channels are registered to the first channel by mixing the two channels on-and-off and by noticing whether the composite image 'moves' or not. A stationary image when mixing is taken in-and-out and means a registered image.

4. Operating the Analog Mode - This mode of operation is equivalent to the operation of ordinary additive color viewers. Effectively, the MCFV projects the imagery in each of the three channels in the colors of blue, green and red, the shades of each color depending on the 'brightness' of the scene (i.e., the radiance level of the particular picture element). The intensity of each channel can be adjusted also. This mode of operation normally gives an overall nice image without strong enhancement of specific features.

5. Operating the Digital Mode - This allows specific colors to be assigned to various intervals of intensity in a single channel. Thus, specific features can easily be accented against the background. The operator should try to assign various highly contrasting colors to different features which hopefully have different spectral characteristics. This mode of operation can, however, give very weird pictures because of the discrete nature of operation. Most often, the whole scene and the relative locations of features in the scene are unnecessarily suppressed.

6. Operating the Mixed Mode – This mode of operation is the combination of the analog mode and the digital mode. This mode is highly desirable because it embodies the advantages of the two modes of operation. Highly enhanced features in the midst of a very informational false-color background can usually be obtained.

7. Hardcopy Output – A permanent record of the display can be obtained by photographing the display screen with a 70-mm Hasselblad camera and Ektachrome color film. The settings on the analog processor and digital processor can be copied by hand and/or through the use of the online recorder.

C-2

APPENDIX C

STANDARD LARSYS-TYPE PROCEDURE AT JSC

1. Preparation of Data – The specific ERTS CCT (the one tape out of the four that cover the desired ERTS frame) is selected with the aid of topographic maps available at the Project Support Office (PSO). This ERTS tape is in the GSFC format and needs to be reformatted on the DAS to MSDS format, during which process scaled edits of the study area can be made. At the same time, the edited tapes can be screened on the DAS, using the MOPS program.[1] If the edits are satisfactory, they can be reformatted on the DAS to LARSYS II format which is acceptable to the UNIVAC 1108 computers and the ERIPS interactive system. All these tapes are in 9-track 800-bpi formats.

2. ERIPS Processing – The ERIPS system is a real-time interactive system. A complete set of operational procedures and tape-handling procedures is available in the user's manual (ref. 9). A successful run on the system normally requires 3 to 4 hours. The ERIPS system actually accepts 9-track 800-bpi CCT's in the LARSYS II format as well as in the GSFC ERTS-1 format. These tapes should be made available to the IBM 360/75 computer operator in the computer room about 10 to 15 minutes before the scheduled ERIPS run-time. After appropriate sign-on, the user is ready to perform standard LARSYS classification on his data.

a. Training field selection – In the pattern recognition software package of the ERIPS, images can be screened

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[1]Multispectral program on passive microwave imaging scanner.

in various scales. Areas of interest which contain known features can be delineated through the use of a light pen and are designated as training fields of the appropriate training classes. These fields can have the shape of a concave as well as a convex polyhedron, with a maximum of 10 sides.

b. Statistics calculation – The statistics processor on the ERIPS can be called to calculate the statistical mean and covariances of the training fields and training classes. These characteristics can be displayed in the form of histograms and also in the form of reports.

c. Selection of best channels – The 'divergence' processor on the ERIPS can be called to select the 'best' channels to be used in the classification of the unknown data. In this range analysis using 4-channel data in single-scene single-date studies, this step was deemed unnecessary.

d. Classification – This can be done on the ERIPS itself or on the CYBER 73 computers. In this process, the statistical information from the training classes are utilized in the maximum-likelihood classifier on both systems to identify the unknown data to the closest (spectrally) training class. The ERIPS system generates a black-and-white microfiche character classification map as a final product. To operate on the CYBER 73 computer, a batch system interface (BSI) tape is generated off the ERIPS. This BSI tape contains the unknown data, the statistics information and channel information derived from the ERIPS processing. Operating in this later mode, a DAS compatible tape of the

classified image can be generated, which in turn can be displayed in various color combinations on the DAS. Color film copies can be made on the DAS. At the same time, the CYBER computer also generates a line-printer output of the classification map.

3. Registration and Composition of Data – This capability is also available on the ERIPS. Two images can be registered and composed into a single image with a total number of channels equal to the sum of the number of channels in the two individual images. This was how the temporal set Snook-1/2 and SB-1/2 in this range investigation were created.

APPENDIX D

EXERCISING THE JSC CLUSTERING PROGRAM

1. Preparation of Data – cf appendix C.

2. Making an ISOCLS Run – The ISOCLS program can be run in batch modes on the Univac 1108 computers and accepts only LARSYS II formatted data CCT. Since the Univac 1108 computers at JSC operate mostly with 7-track tapes, it is good practice to reformat (on the Univac 1108 computer) the 9-track tapes (generated on the DAS) to 7-track tapes. A complete program documentation of ISOCLS is found in the user's manual (ref. 6). Essentially, the user inputs the parameter values he so desires when he submits the card-deck to the computer center. The main parameters and their recommended settings have been discussed in section 6.2.2. A run to cluster 100,000 4-channel data roughly takes 2 minutes per iteration. For this amount of data, the Range Analysis Team normally considered that 10 to 15 iterations would produce reasonably stabilized results. To reduce computer run time, sampling schemes could be used, as discussed in section 6.2.4.

3. Interpretation and Display of Clustering Results – The ISOCLS program generates a printout on the line-printer and a DAS compatible tape. The clusters can be studied individually on the DAS for their identification. Then a color-coded classification map can be generated on the DAS on films. It is in this process when clusters are interpreted and identified to known classes by checking clustered areas against ground-truth information.

APPENDIX E

I^2S SETTINGS USED ON SPECIFIED FIGURES

1. SETTINGS FOR THE COLOR ENHANCEMENT OF FIGURE H-1

   (I^2S digital multiband composite of August 30, 1972, ERTS-1 imagery in bands 5, 6, and 7 of Snook site)

   a. Film

      9-1/2 inch (cut) positive transparencies Photographic Technology Division (PTD Copy) frame number 1038-1603

   b. Analog Signal Processor Settings

      <u>Channels I and II</u>: Internal, transmit, +, sliced

      <u>Channel III</u>: Internal, exposure, +, sliced

   c. Photomultiplier

      <u>Channels 1, 2, and 3</u>: 1,000 volts (approximate)

      <u>Reference Channel (4)</u>: 650 volts (approximate)

	Channel 1	Channel 2	Channel 3
Offset	6.64	7.00	7.64
Width	13.04	14.15	14.09

   d. (Digital) Color Contrast Values

<u>Channel I</u>	Offset:	06.64
	Width:	13.04
<u>Channel II</u>	Offset:	07.00
	Width:	14.15
<u>Channel III</u>	Offset:	07.64
	Width:	14.09

e. Digital Image Processor Settings

Slice		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Channel 1 (Band 5)	Red Level	*															
	Green Level																
	Blue Level																
Channel 2 (Band 6)	Red Level																
	Green Level																
	Blue Level																
Channel 3 (Band 7)	Red Level		9		5	8				7	8	12	6	13	6	6	15
	Green Level		8			8	11	10	10	11	12		14	3	8	11	
	Blue Level				6	8		10		6	9		5				

*Blank = Neutral Setting

2. SETTINGS FOR THE COLOR ENHANCEMENT OF FIGURE H-2

(I^2S digital multiband composite of November 10, 1972, ERTS-1 imagery in bands 4, 5, and 7 of Snook site)

a. Film

9-1/2 inch (cut) positive transparencies (PTD Copy) frame number 1110-16311

b. Analog Signal Processor Settings

Channels I, II, and III: Internal, transmit, +, sliced

c. Photomultiplier

Channels I, II, and III: 1,000 volts (approximate)

Reference Channel (4): 600 volts (approximate)

	Channel 1	Channel 2	Channel 3
Offset	Not Recorded	8.83	4.91
Width	Not Recorded	10.6	13.92

d. Digital Image Processor Settings

Slice		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Channel 1 (Band 4)	Red Level	*															
	Green Level		7	7													
	Blue Level															8	8
Channel 2 (Band 7)	Red Level		9	9	8									8			
	Green Level		15	15	15												
	Blue Level		15			11	10	15	15	15	15	15	15				
Channel 3 (Band 5)	Red Level			15	15	15	15	15	15	15	15	15	14	14	14	14	14
	Green Level		6	13	14	14	8	8	8								
	Blue Level								14	14				5	5		

*Blank = Neutral Setting

3. SETTINGS FOR THE COLOR ENHANCEMENT OF FIGURE H-3

(I^2S analog and digital multiband composite of December 16, 1972, ERTS-1, imagery in bands 4, 5, and 7 of Snook site)

a. Film

9-1/2 inch (cut) positive transparencies (PTD Copy) frame number 1146-16311

b. Analog Signal Processor Settings

Channel I (Band 4): Internal, exposure, negative, normal

Channel II (Band 5): Internal, exposure, +, sliced

Channel III (Band 7): Internal, transmit, +, sliced

c. Photomultiplier

Channels I, II, and III: 1,000 volts (approximate)

Reference Channel (1): 600 volts (approximate)

d. (Digital) Color Contrast Values

Channel III

Offset: 8.54
Width: 10.18

e. Digital Image Processor Settings

Slice		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Channel 1 (Band 5)	Red Level	*															
	Green Level		15	15	14	13	13	15	14	12	12	12					
	Blue Level																
Channel 2 (Band 6)	Red Level																
	Green Level				12	12	12	12	12	12	12	12	12	9			
	Blue Level						9							8	8		
Channel 3 (Band 7)	Red Level				14	10	10	11	14	14	13	10	10	10	13	13	12
	Green Level			10	14	14											
	Blue Level			13	13	13	13	14	10	8							

*Blank = Neutral Setting

4. SETTINGS FOR THE COLOR ENHANCEMENT OF FIGURE H-4

(I^2S analog multiband temporal composite of August 30, 1972, ERTS-1 imagery band 7 (blue), November 10, band 7 (green), and December 16, band 7 (red) of Snook site)

a. Film

9-1/2 inch (cut) positive transparencies –
frame number 1038-16303 (Goddard Copy)
frame number 1110-16311 (PTD Copy)
frame number 1146-16311 (PTD Copy)

b. Analog Signal Processor Settings

Channel I (August 30)

Band 7 imaged blue
Internal, transmit, +, sliced

Channel II (November 10)

Band 7 imaged green
Internal, transmit, +, sliced

Channel III (December 16)

Band 7 imaged red
Internal, transmit, +, sliced

c. Photomultiplier

Channels I, II, and III: 1,000 volts (approximate)

Reference Channel (4): 650 volts (approximate)

5. SETTINGS FOR THE COLOR ENHANCEMENT OF FIGURE H-8

(I^2S analog multiband composite of October 4, ERTS-1 imagery in bands 4 (blue), 5 (green), and 7 (red) of San Bernard site)

a. Film

9-1/2 inch (cut) positive transparencies (PTD Copy), frame number 1073-16251

b. Analog Signal Processor Settings

Channel I

Band 4 — Blue image
Internal, transmit, +, sliced

Channel II

Band 5 — Green image
Internal, exposure, negative, slice

Channel III

Band 7 — Red image
Internal, transmit, +, slice

c. Photomultiplier

Channel I, II, and III: 1,000 volts (approximate)

Reference Channel (4): 600 volts (approximate)

6. SETTINGS FOR THE COLOR ENHANCEMENT OF FIGURE H-9

(I^2S digital multiband composite of November 27, 1972, ERTS-1 imagery in bands 4, 5, and 7 of San Bernard site)

a. Film

9-1/2 inch (cut) positive transparencies (PTD Copy), frame number 1127-16260

b. No analog or digital processor settings recorded

7. SETTINGS FOR THE COLOR ENHANCEMENT OF FIGURE H-10

(I^{2}S digital multiband composite of November 27, 1972, ERTS-1 imagery in bands 4, 5, and 7 of San Bernard site)

a. Film

9-1/2 inch (cut) positive transparencies (PTD Copy), ERTS frame number 1127-16260

b. No analog or digital processor settings recorded

APPENDIX F
LOCATION OF SNOOK SITE FIELDS

1. Coordinates of the training fields of the Snook study site with reference to the Snook-1 scene (1038-16303-MB-3)

Field	Symbol	First Coor. (line sample)	Second Coor. (line sample)	Third Coor. (line sample)	Fourth Coor. (line sample)	Fifth Coor. (line sample)	Sixth Coor. (line sample)
Bottomland	B	932 1984	941 1991	942 1979	949 1976	935 1964	935 1976
Bermuda, Class A	C	870 2017	867 2024	862 2022	866 2013		
Bermuda, Class B	D	926 2073	918 2090	914 2088	918 2083	921 2070	
Bottomland Hardwood	H	891 1888	897 1905	889 1910	884 1893		
Mesquite	M	774 2093	771 2098	770 2103	762 2097	766 2096	766 2089
Oak, dense	O	922 2025	925 2033	918 2038	904 2032	912 2024	
Oak, sparse	P	836 2056	843 2060	841 2065	836 2066	838 2062	836 2061
Abandoned Cropland, Class A	W	825 2065	821 2067	821 2073	825 2073	826 2067	
Abandoned Cropland, Class B	X	827 2067	826 2072	829 2072	832 2072	832 2071	
Water	Z	991 2084	990 2108	976 2110	974 2085		

2. Coordinates of the test fields of the Snook study site with reference to the Snook-1 scene (1038-16303-MB-3)

Field	Symbol	First Coor. (line sample)	Second Coor. (line sample)	Third Coor. (line sample)	Fourth Coor. (line sample)	Fifth Coor. (line sample)	Sixth Coor. (line sample)
Bermuda, Class A	C1	869 2016	862 2021	859 2026			
Bermuda, Class A	C2	866 2068	862 2074	855 2067	861 2065		
Bermuda, Class B	D	941 2055	944 2062	942 2066	939 2061	939 2057	
Bottomland Hardwood	H	898 1865	906 1889	901 1890	894 1875		
Oak, dense	O	861 2000	864 2006	861 2014	853 2010	856 2006	857 2007
Abandoned Cropland, Class A	X	830 2065	825 2061	825 2051	829 2050		
Water	Z	981 2101	981 2114	973 2113	972 2101	980 2102	

APPENDIX :

LOCATION OF SAN BERNARD SITE FIELDS

1. Coordinates of the training fields of the San Bernard study site with reference to the SB-1 scene (1073-16251-MB-3)

Field	Symbol	First Coor. (line sample)	Second Coor. (line sample)	Third Coor. (line sample)	Fourth Coor. (line sample)	Fifth Coor. (line sample)	Sixth Coor. (line sample)
Burned Gulf Cordgrass	B	1126 1911	1130 1920	1115 1922	1115 1912		
Bare Soil	C	1130 1730	1128 1726	1129 1724	1126 1710	1127 1711	1131 1724
Gulf Cordgrass	G	1101 1925	1093 1920	1100 1896	1107 1900		
Marshhay Cordgrass	M1	1139 1886	1133 1898	1128 1898	1130 1888		
Marshhay Cordgrass	M2	1121 1850	1122 1864	1112 1867	1111 1843		
Oak	O	1051 1922	1047 1936	1040 1936	1039 1919		
Smutgrass	S	1001 1885	986 1891	986 1904	996 1906		
Coastal Water	X	1200 1847	1205 1854	1202 1862	1195 1866	1182 1851	
Inland Water	Y	1153 1862	1159 1870	1160 1880	1152 1881	1146 1868	1151 1862
Deep-sea Water	Z	1210 1669	1210 1701	1183 1701	1183 1670		

2. Coordinates of the test fields of the San Bernard study site with reference to the SB-1 scene (1073-16251-MB-3)

Field	Symbol	First Coor. (line sample)	Second Coor. (line sample)	Third Coor. (line sample)	Fourth Coor. (line sample)	Fifth Coor. (line sample)	Sixth Coor. (line sample)
Burned Gulf Cordgrass	B	1213 1927	1211 1945	1199 1950	1205 1926		
Bare Soil	C	1189 1874	1179 1859	1180 1838	1191 1874		
Gulf Cordgrass	G	1068 1890	1070 1905	1056 1905	1056 1896		
Marshhay Cordgrass	M	1138 1885	1133 1896	1126 1896	1130 1887	1139 1884	

APPENDIX H

COLOR ENHANCEMENTS OF ERTS-1 FILM IMAGERY PRODUCED ON THE I^2S MODEL 2000 MCFV AND ON THE ITEK ACVP

NASA S-73-31455

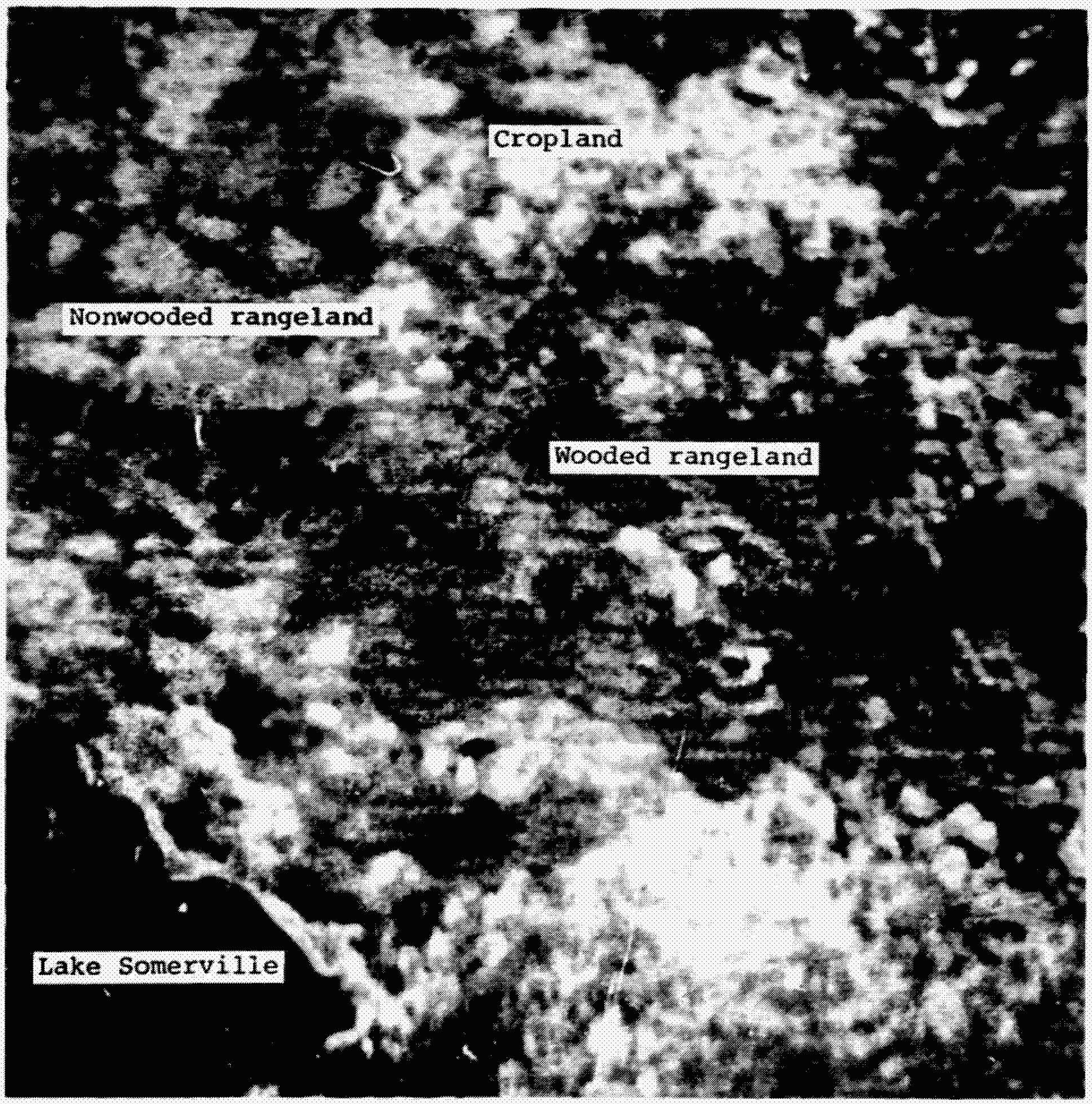

Figure H-1.- I^2S digital multiband composite of bands 5, 6, and 7 (ERTS-1 film imagery of Snook site acquired August 30, 1972).

NASA S-73-28050

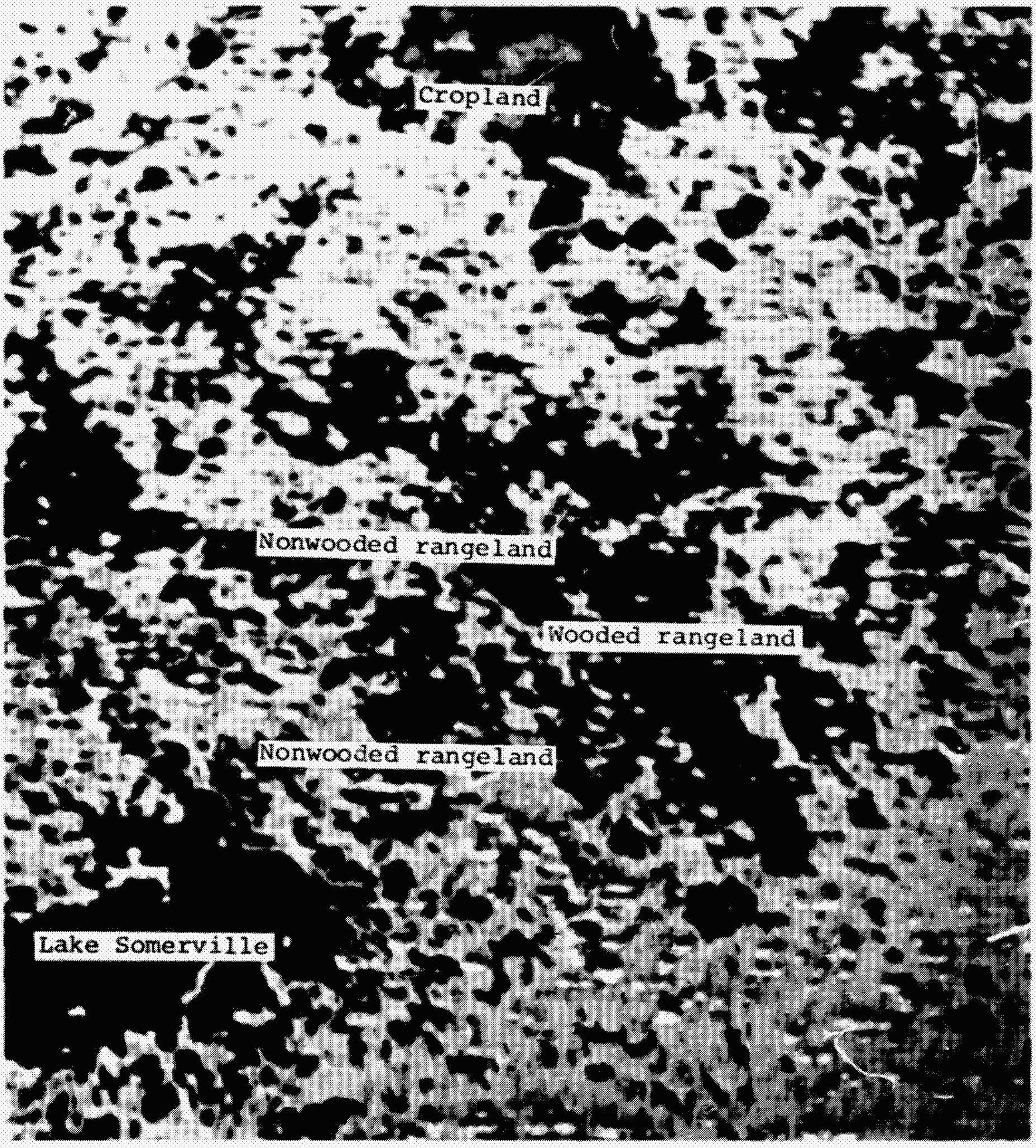

Figure H-2.- I^2S digital multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery acquired over Snook site November 10, 1972).

NASA S-73-2805

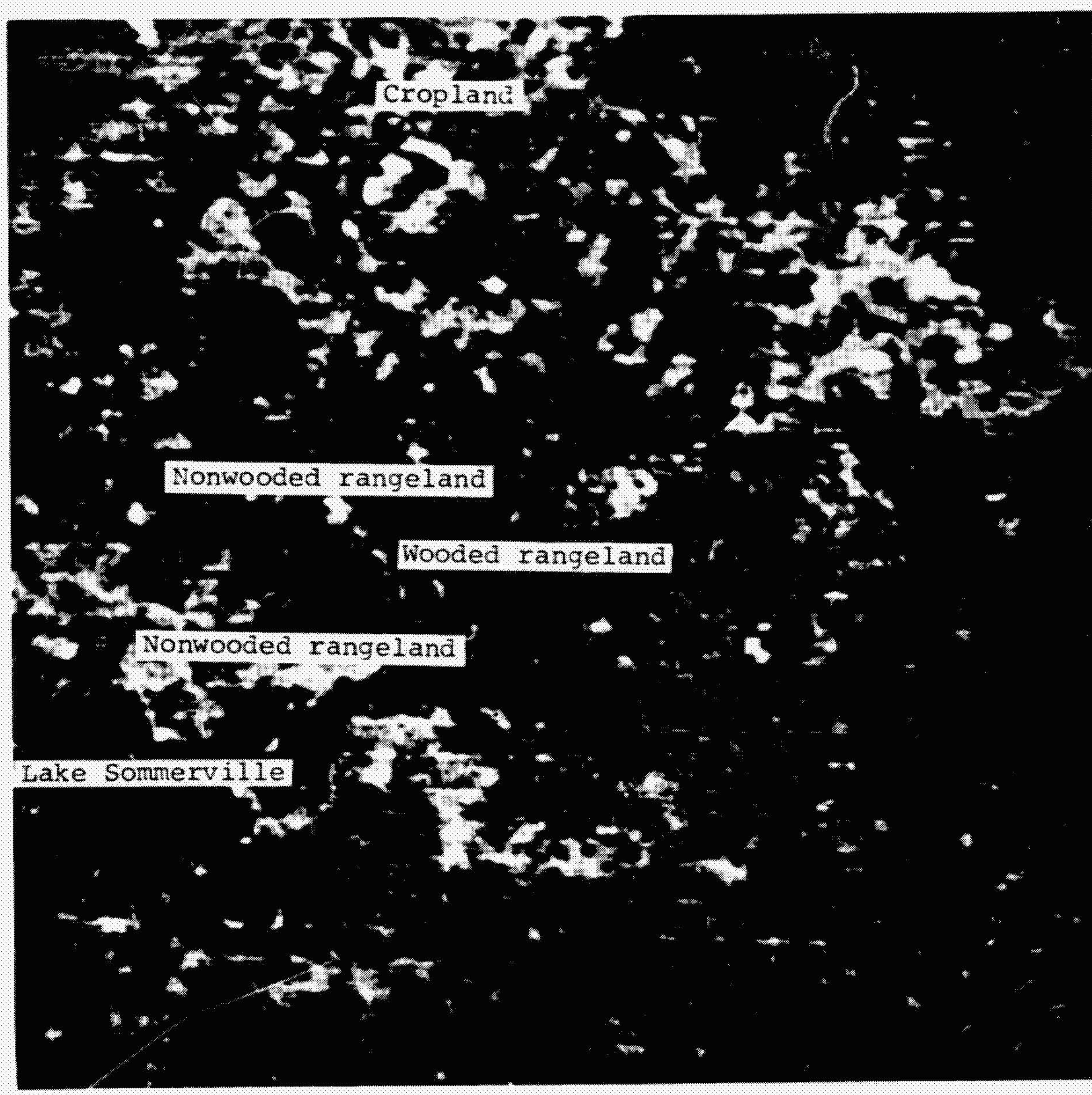

Figure H-3.- I^2S analog and digital multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery of Snook site acquired December 16, 1972).

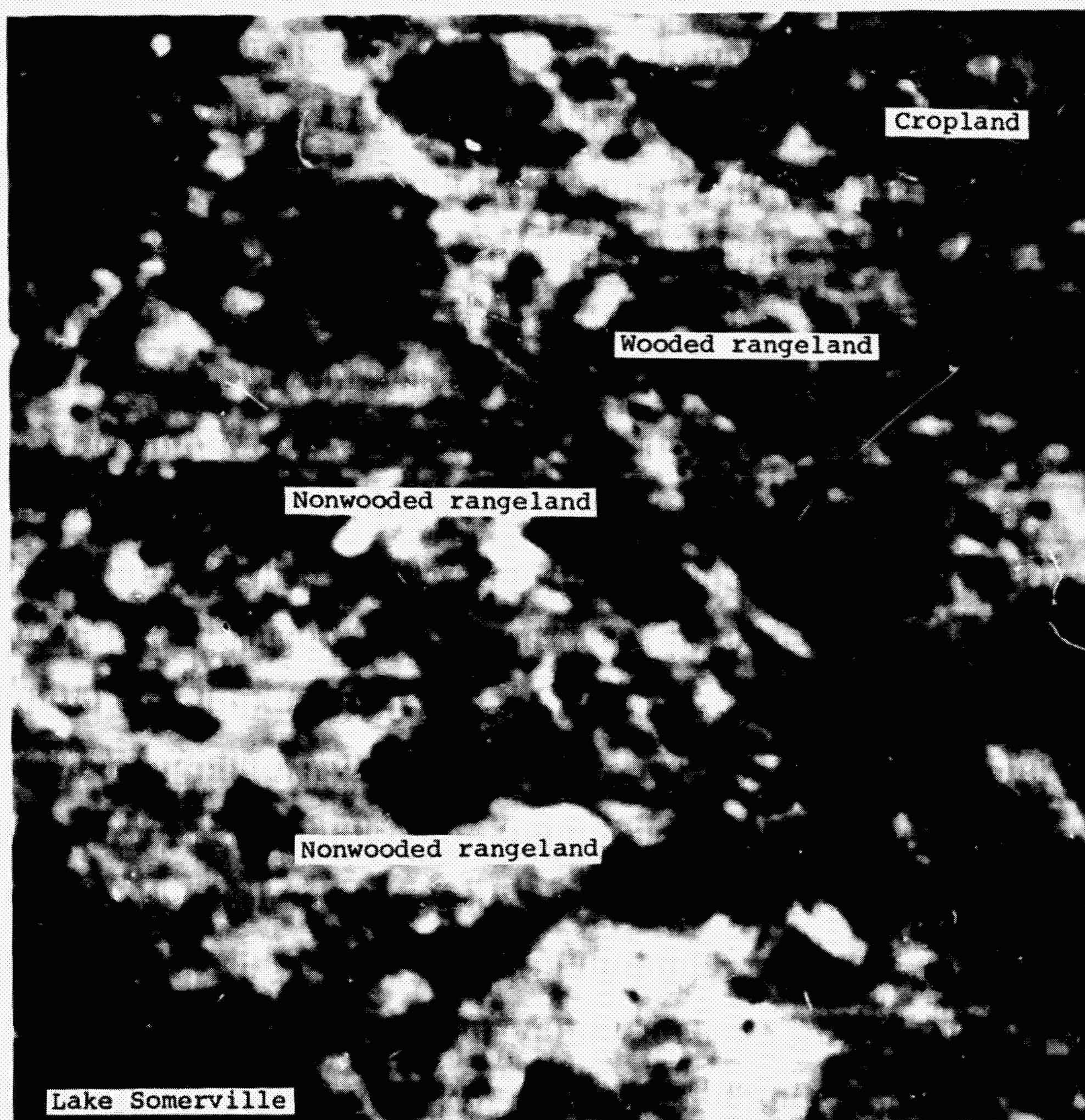

Figure H-4.- I^2S analog multiband temporal composite of ERTS-1 film imagery of Snook site - imagery of August 30, 1972, band 7 (blue); November 10, 1972, band 7 (green); December 16, 1972, band 7 (red).

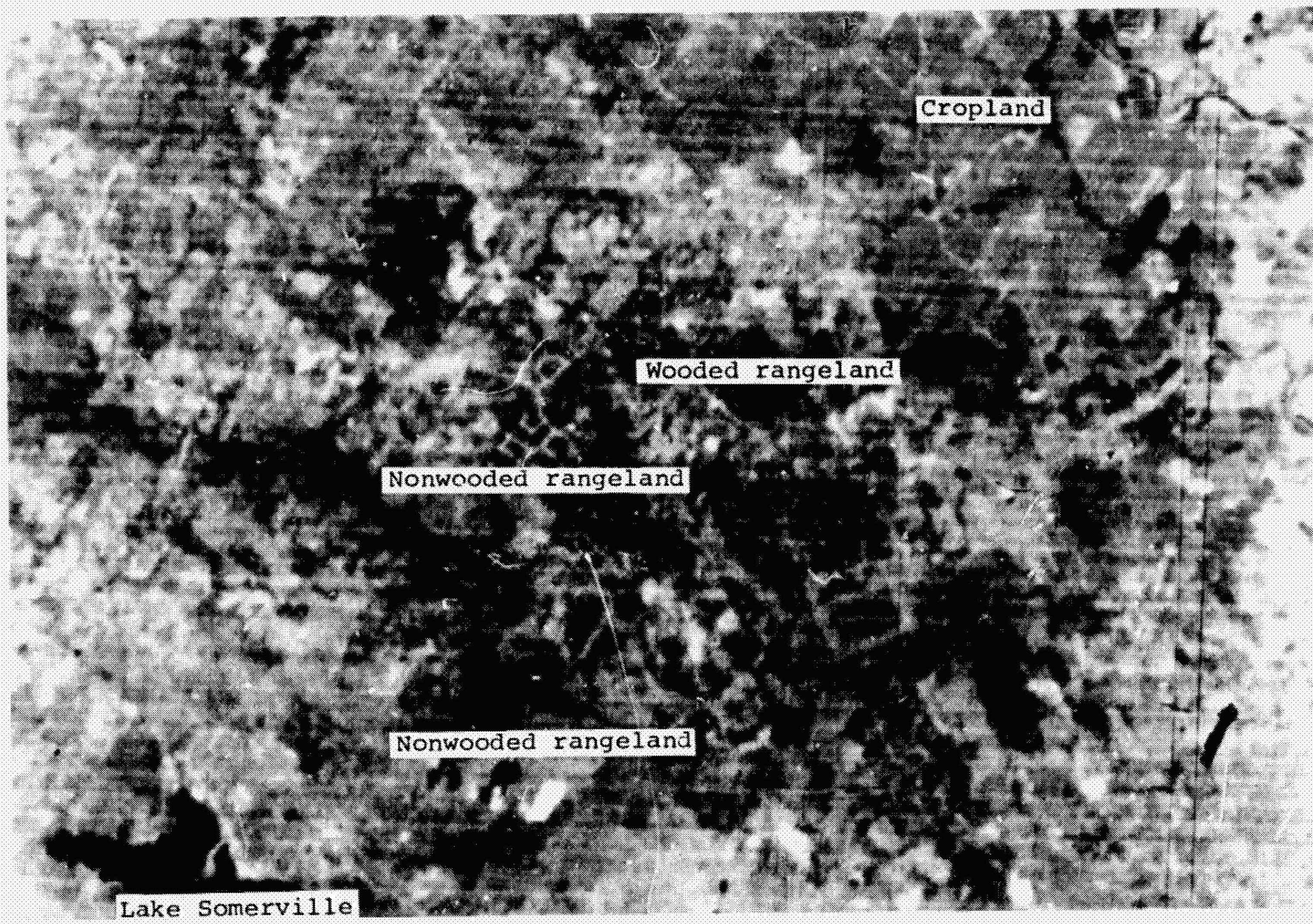

Figure H-5.- Additive color viewer/printer (ACVP) multiband composite of Snook site (ERTS-1 film imagery acquired August 30, 1972 - band 4, blue; band 5, green; band 7, red).

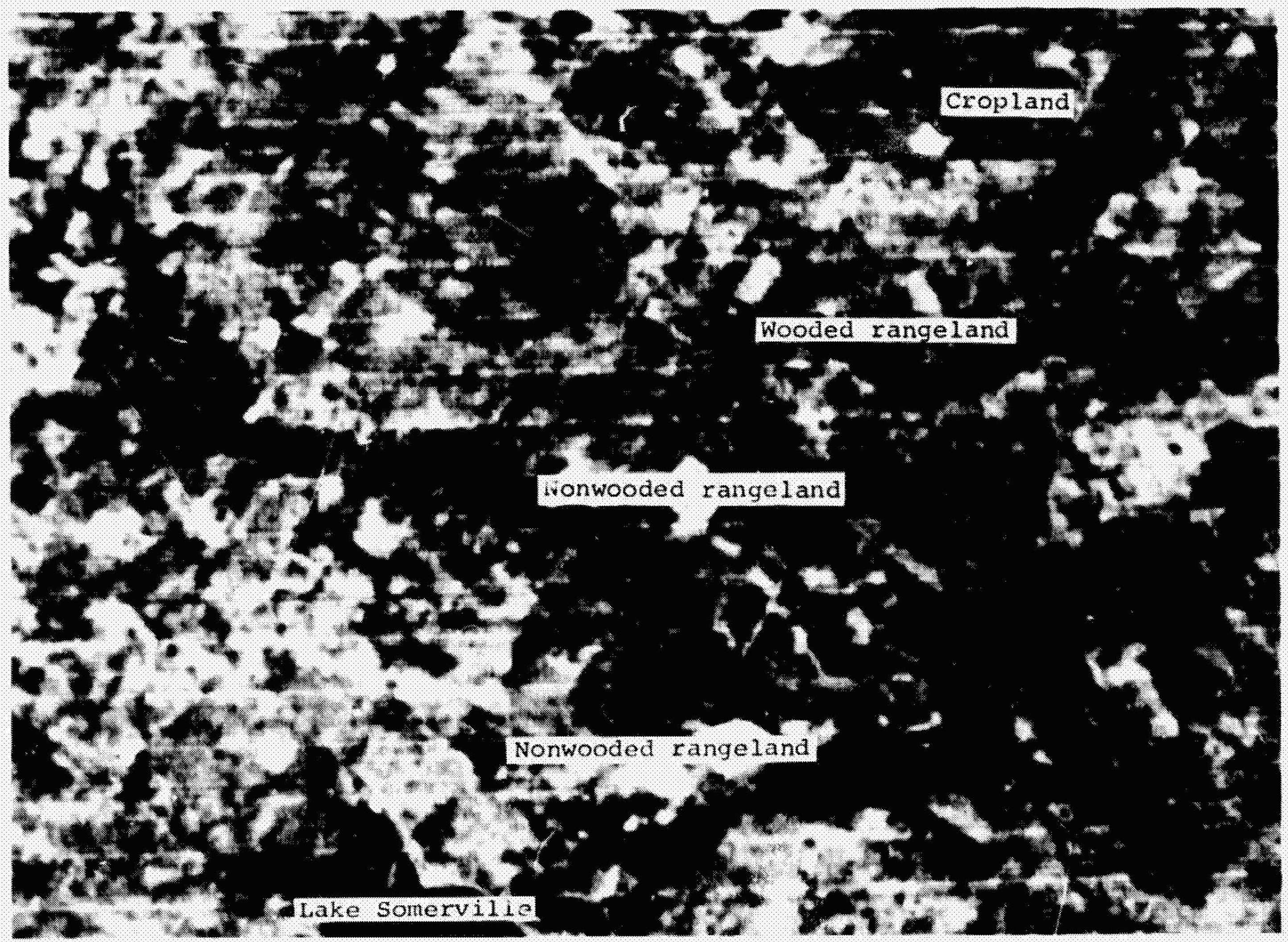

Figure H-6.- ACVP multiband composite of Snook site (ERTS-1 film imagery acquired December 16, 1972 - band 4, blue; band 5, green; band 7, red).

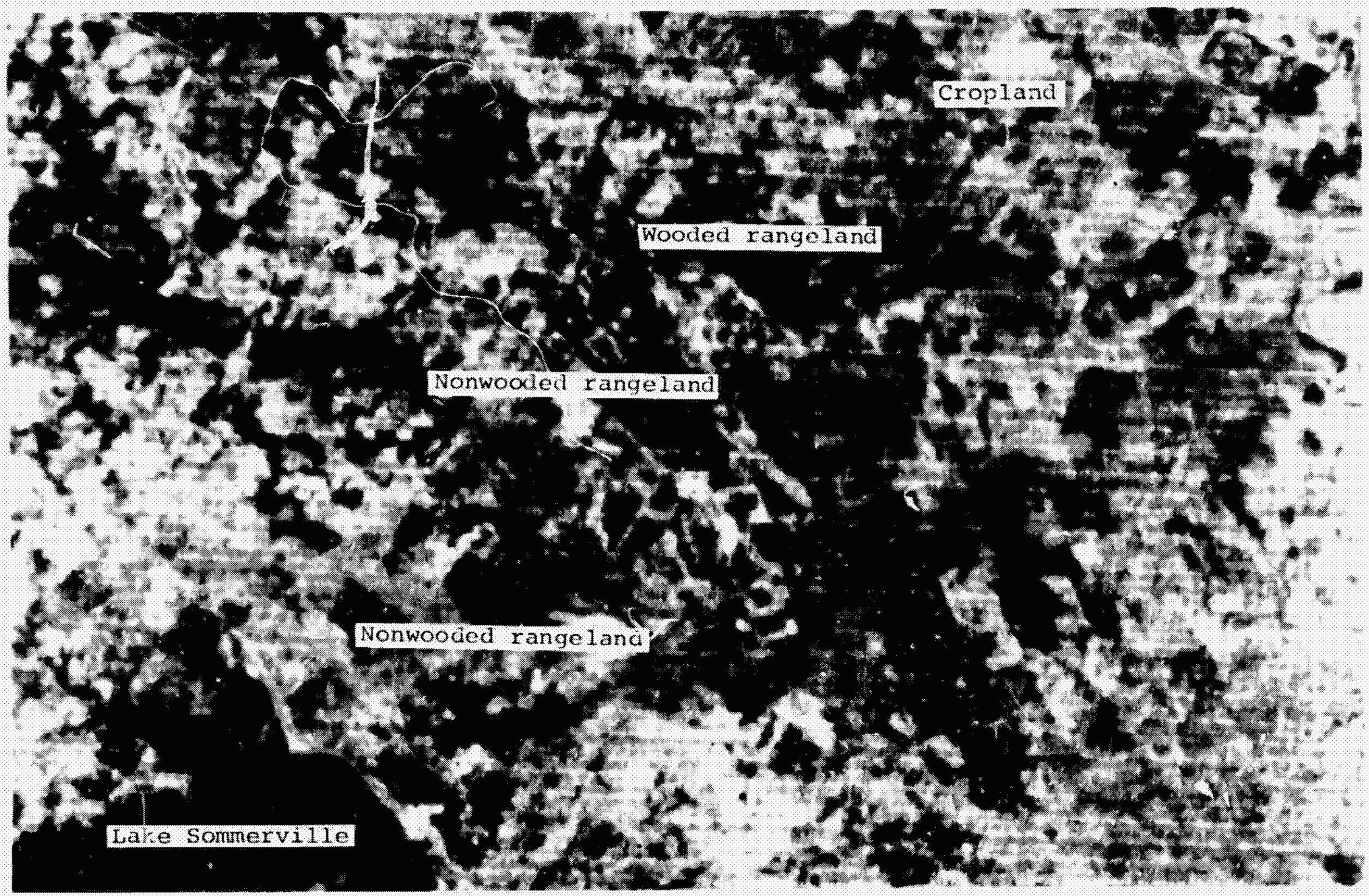

Figure H-7.- ACVP multiband temporal composite of ERTS-1 film imagery of Snook site (band 7, red, acquired August 30, 1972; band 7, green, acquired November 10, 1972).

NASA S-73-28049

Figure H-8.- I^2S analog multiband composite of San Bernard site (ERTS-1 film imagery acquired October 4, 1972; band 4, blue; band 5, green; and band 7, red).

NASA S-73-28055

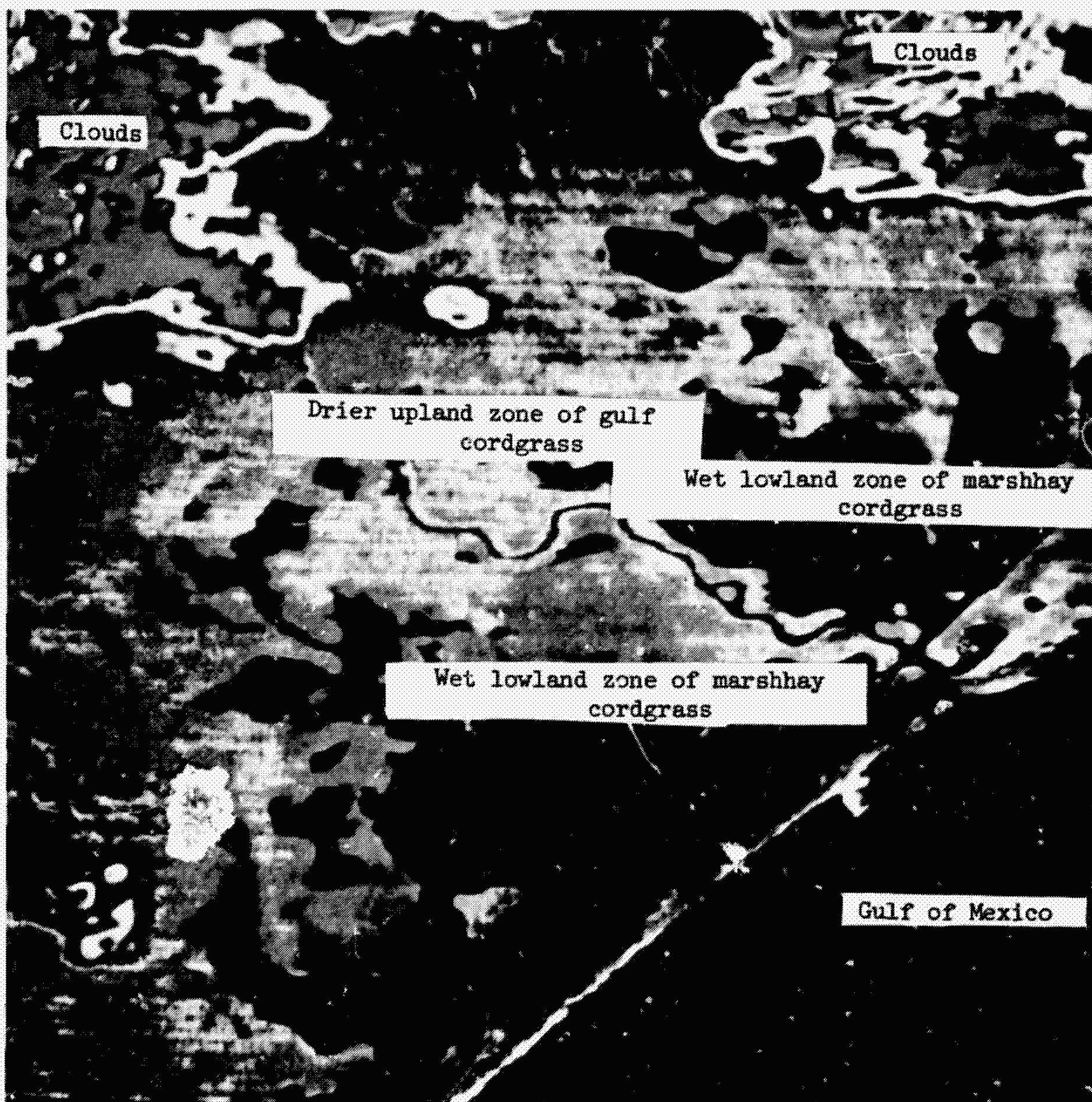

Figure H-9.- I^2S digital multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery of San Bernard site acquired November 27, 1972).

NASA S-73-28056

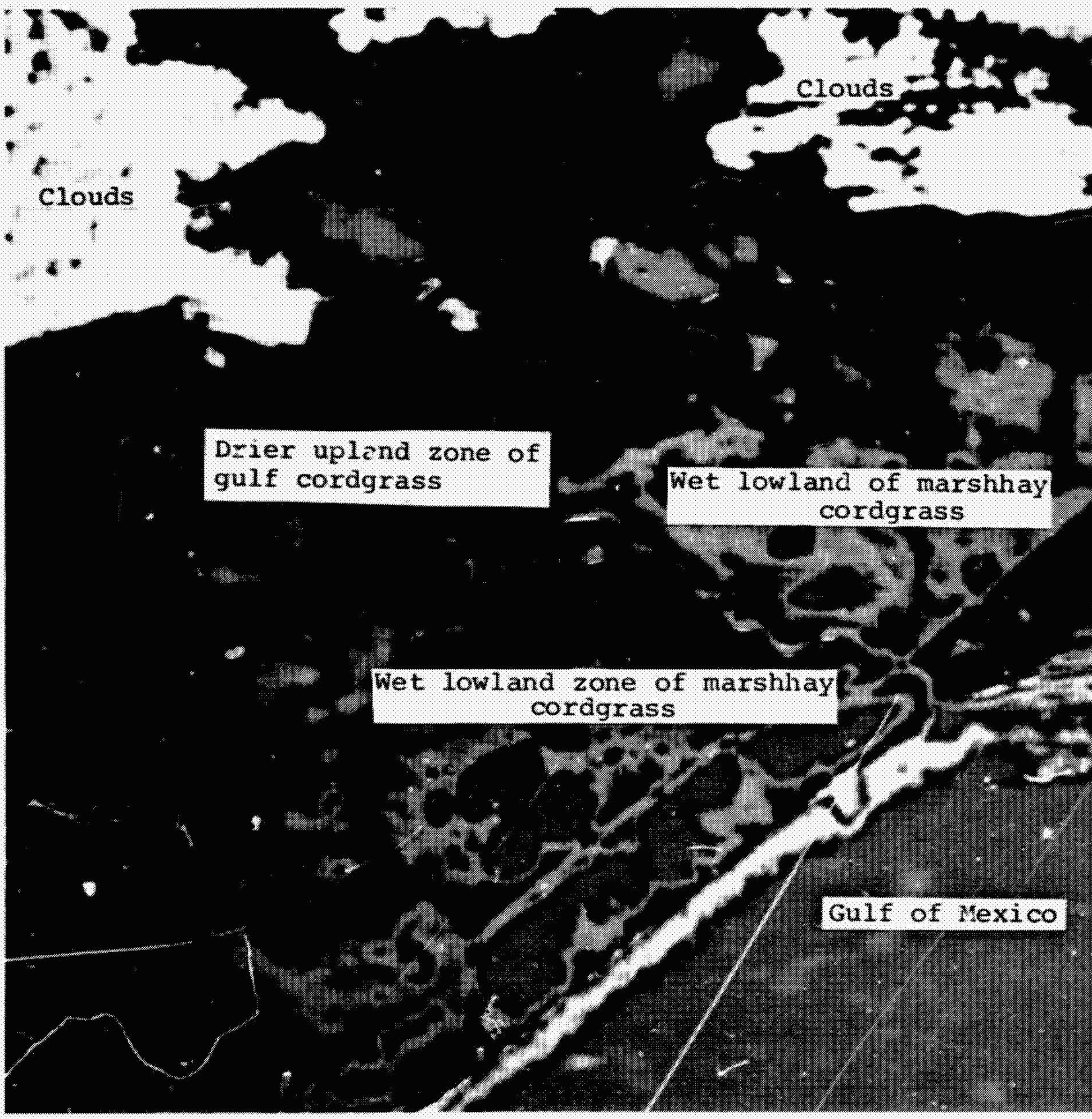

Figure H-10.- I^2S digital multiband composite of bands 4, 5, and 7 (ERTS-1 film imagery of San Bernard site acquired November 27, 1972).

NASA S-73-31456

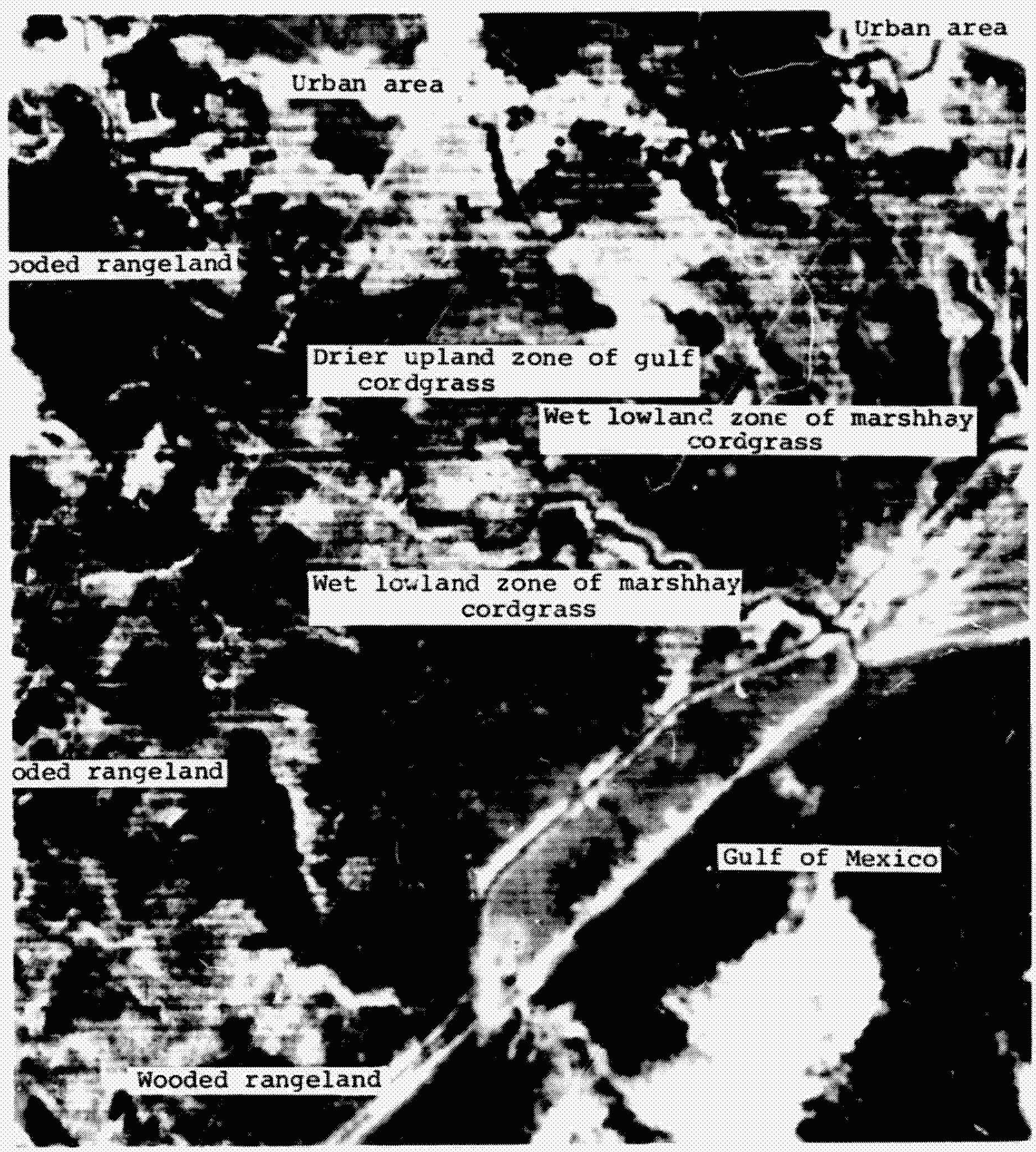

Figure H-11.- ACVP multiband composite of band 4, blue; band 5, green; and band 7, red (ERTS-1 film imagery of San Bernard site acquired October 4, 1972).

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APPENDIX I

CLASSIFICATION TABLES AND MAPS OF ERTS-1 DIGITAL TAPE DATA USING THE SUPERVISED CLASSIFICATION TECHNIQUE LARSYS

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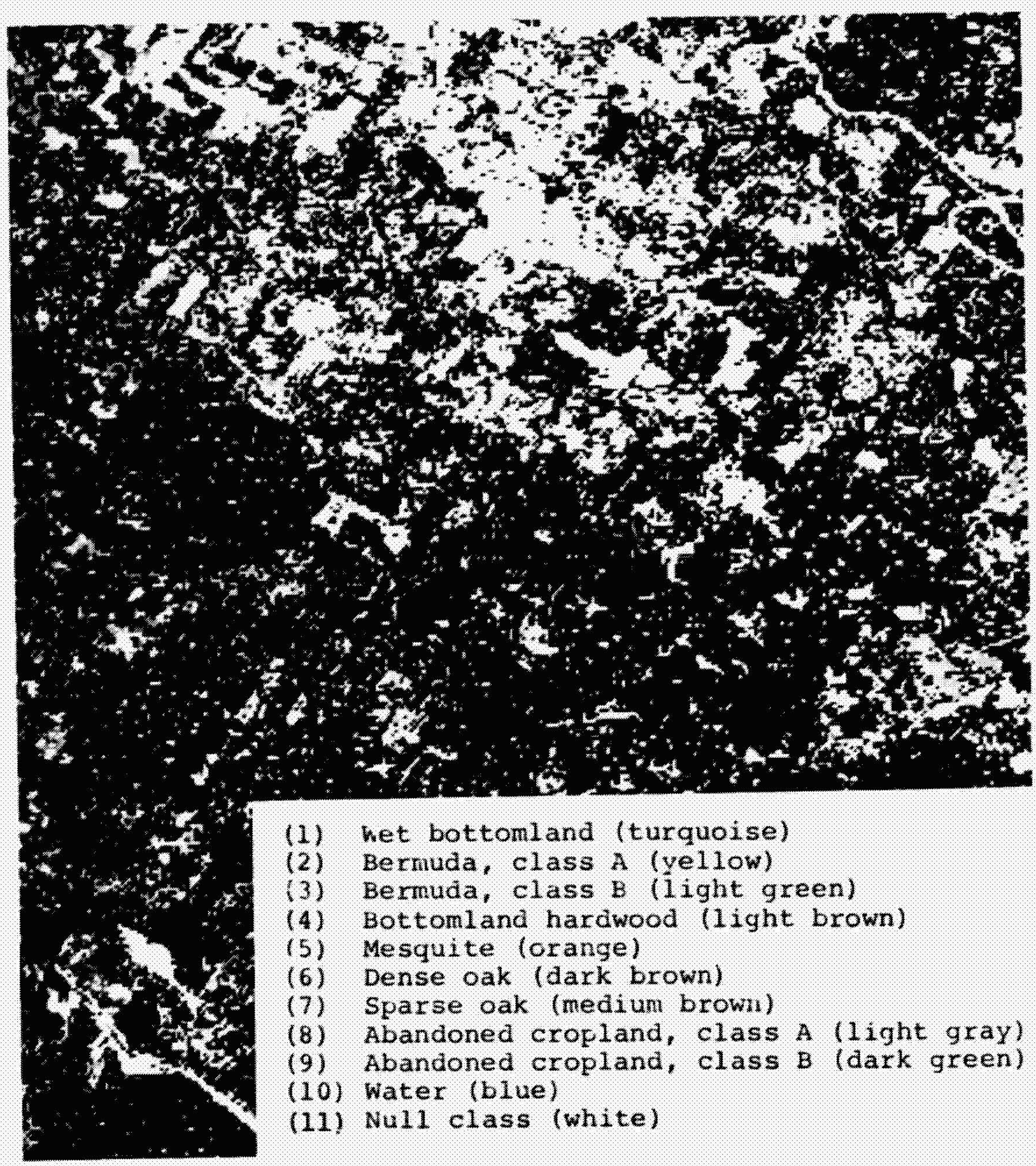

Figure I-1.- CYBER 73 LARSYS classification of Snook-1 data with 2-percent thresholding.

TABLE I-I.- SNOOK-1 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples										
			B	C	D	H	M	O	P	W	X	Z	Thres.
B	219	90.0	197	0	10	0	0	0	0	0	7	0	5
C	56	82.1	0	46	2	0	3	0	0	1	3	0	1
D	94	.67.0	3	1	63	0	0	0	2	10	15	0	0
H	170	92.4	0	0	2	157	1	3	0	6	0	0	1
M	93	66.7	0	3	6	0	62	2	19	1	0	0	0
O	250	96.4	0	0	0	0	1	241	5	0	0	0	3
P	55	72.7	0	1	2	0	6	1	40	3	2	0	0
W	42	50.0	0	1	6	0	5	0	3	21	6	0	0
X	25	72.0	0	0	6	0	1	0	0	0	18	0	0
Z	399	95.0	0	0	0	0	0	0	0	0	0	379	20

Overall Classification Accuracy = 78.5 percent

B = Bottomland
C = Bermuda, class A
D = Bermuda, class B
H = Bottomland hardwood
M = Mesquite
O = Oak (dense)
P = Oak (sparse)
W = Abandoned cropland, class A
X = Abandoned cropland, class B
Z = Water
Thres. = Thresholded

TABLE I-II.- SNOOK-1 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples										
			B	C	D	H	M	O	P	W	X	Z	Thres.
C1	24	58.3	0	14	0	0	9	0	1	0	0	0	0
C2	60	78.3	0	47	0	0	7	4	1	0	0	0	1
D	39	43.6	2	3	17	1	0	1	2	6	7	0	0
H	143	72.0	0	0	0	103	0	10	19	9	0	0	2
O	87	44.8	0	0	0	21	0	39	13	0	1	0	13
X	67	71.6	0	1	0	0	0	0	0	0	48	0	18
Z	119	89.9	0	0	0	0	0	0	0	0	0	107	12
Whole Test Area	122,500		3,566	20,420	6,784	6,908	15,857	10,926	14,033	7,549	9,492	1,787	25,178

Overall Classification Accuracy = 56.5 percent

C1 = Bermuda, class A, field 1
C2 = Bermuda, class A, field 2
D = Bermuda, class B
H = Bottomland hardwood
O = Oak
X = Abandoned cropland, class B
Z = Water
Thres. = Thresholded

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Figure I-2.- CYBER 73 LARSYS classification of Snook-2 data with 2-percent thresholding.

TABLE I-III.- SNOOK-2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples										
			B	C	D	H	M	O	P	W	X	Z	Thres.
B	219	86.0	189	0	0	11	1	0	9	1	6	0	2
C	56	93.0	0	52	4	0	0	0	0	0	0	0	0
D	94	67.0	0	6	63	0	5	0	0	2	15	0	3
H	170	79.0	6	0	0	135	1	9	17	0	0	0	2
M	93	55.0	3	0	6	0	51	0	14	4	15	0	0
O	250	90.0	0	0	0	19	0	226	3	0	0	0	2
P	55	47.0	3	0	0	19	4	2	26	0	1	0	0
W	42	76.0	0	0	3	0	1	0	0	32	5	0	1
X	25	64.0	1	0	1	0	3	0	0	4	16	0	0
Z	399	97.0	0	0	0	0	0	0	0	0	0	388	11

Overall Classification Accuracy = 75.4 percent

B = Bottomland C = Bermuda, class A D = Bermuda, class B
H = Bottomland hardwood M = Mesquite O = Oak (dense)
P = Oak (sparse) W = Abandoned cropland, class A X = Abandoned cropland, class B
Z = Water Thres. = Thresholded

TABLE I-IV.- SNOOK-2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples										
			B	C	D	H	M	O	P	W	X	Z	Thres.
C1	24	21.0	0	5	17	1	1	0	0	0	0	0	0
C2	60	46.7	0	28	6	2	4	5	2	0	0	0	13
D	39	36.0	0	5	14	0	6	0	1	1	3	0	9
H	143	62.0	17	0	0	89	2	8	22	0	0	0	5
O	87	26.0	2	0	2	32	5	23	8	0	0	0	15
X	67	9.0	0	0	12	0	8	0	3	27	6	0	11
Z	119	98.0	0	0	0	0	0	0	0	0	0	117	2
Whole Test Area	122,500		6,579	5,538	15,846	12,922	15,001	18,974	11,052	6,268	10,025	2,796	27,519

Overall Classification Accuracy = 42.7

C1 = Bermuda, class A, field 1
H = Bottomland hardwood
E = Water
Thres. = Thresholded
C2 = Bermuda, class A, field 2
O = Oaks
X = Abandoned cropland, class B
D = Bermuda, class B

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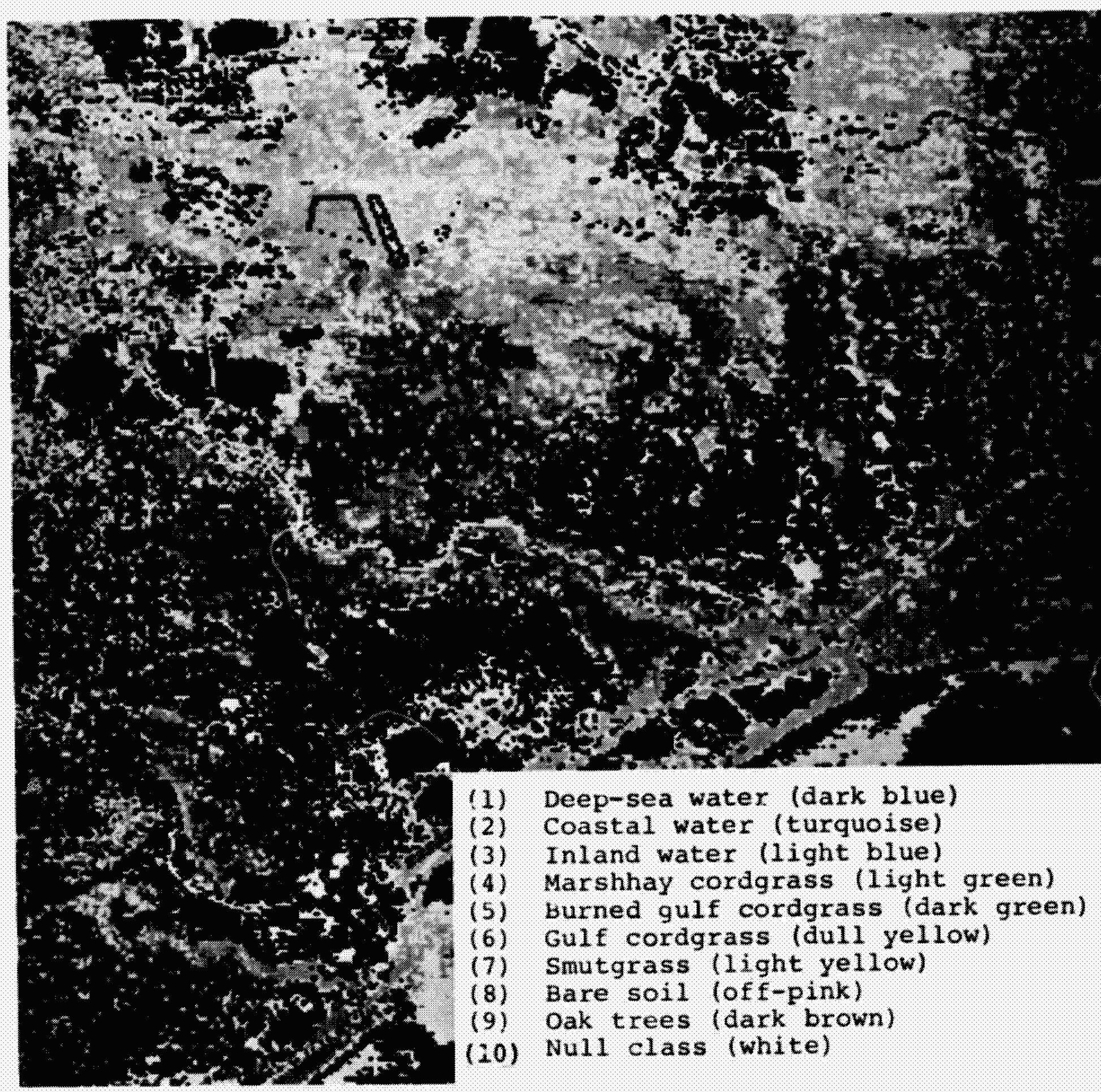

Figure I-3.- CYBER 73 LARSYS classification of San Bernard-1 data with 2-percent thresholding.

TABLE I-V.- SB-1 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples									
			B	C	G	M	O	S	X	Y	Z	Thres.
B	148	95.3	141	0	0	6	0	0	0	0	0	1
C	36	94.4	0	34	0	0	0	1	1	0	0	0
G	229	77.7	0	1	178	0	0	49	0	0	0	1
M1	85	95.5	1	0	0	81	0	0	0	0	0	3
M2	201	81.1	3	0	0	197	0	0	0	0	0	1
O	165	96.4	0	1	0	0	159	0	0	0	0	5
S	230	77.4	0	0	48	1	0	178	0	0	0	3
X	263	93.2	0	0	0	0	0	0	245	0	0	18
Y	187	97.9	0	1	0	0	0	0	0	183	0	3
Z	910	97.5	0	0	0	0	0	0	0	0	887	23

Overall Classification Accuracy = 92.3

B = Burned gulf cordgrass
M1 = Marshhay cordgrass, field 1
S = Smutgrass

C = Bare soil
M2 = Marshhay cordgrass, field 2
X = Coastal water

G = Gulf cordgrass
O = Oak
Y = Inland water

Z = Deep-sea water
Thres. = Thresholded

TABLE I-VI.- SB-1 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples									
			B	C	G	M	O	S	X	Y	Z	Thres.
B	218	81.7	178	3	0	18	0	0	0	0	0	19
C	44	90.9	0	40	3	0	0	0	0	0	0	1
G	182	95.1	0	0	173	0	0	5	0	0	0	4
M	88	96.6	1	0	9	85	0	0	0	0	0	2
Whole Test Area	129,200		7,681	19,247	23,145	12,468	6,414	18,268	3,441	1,556	10,118	34,852

Overall Classification Accuracy = 91.1

B = Burned gulf cordgrass C = Bare soil G = Gulf cordgrass
M = Marshhay cordgrass Thres. = Thresholded

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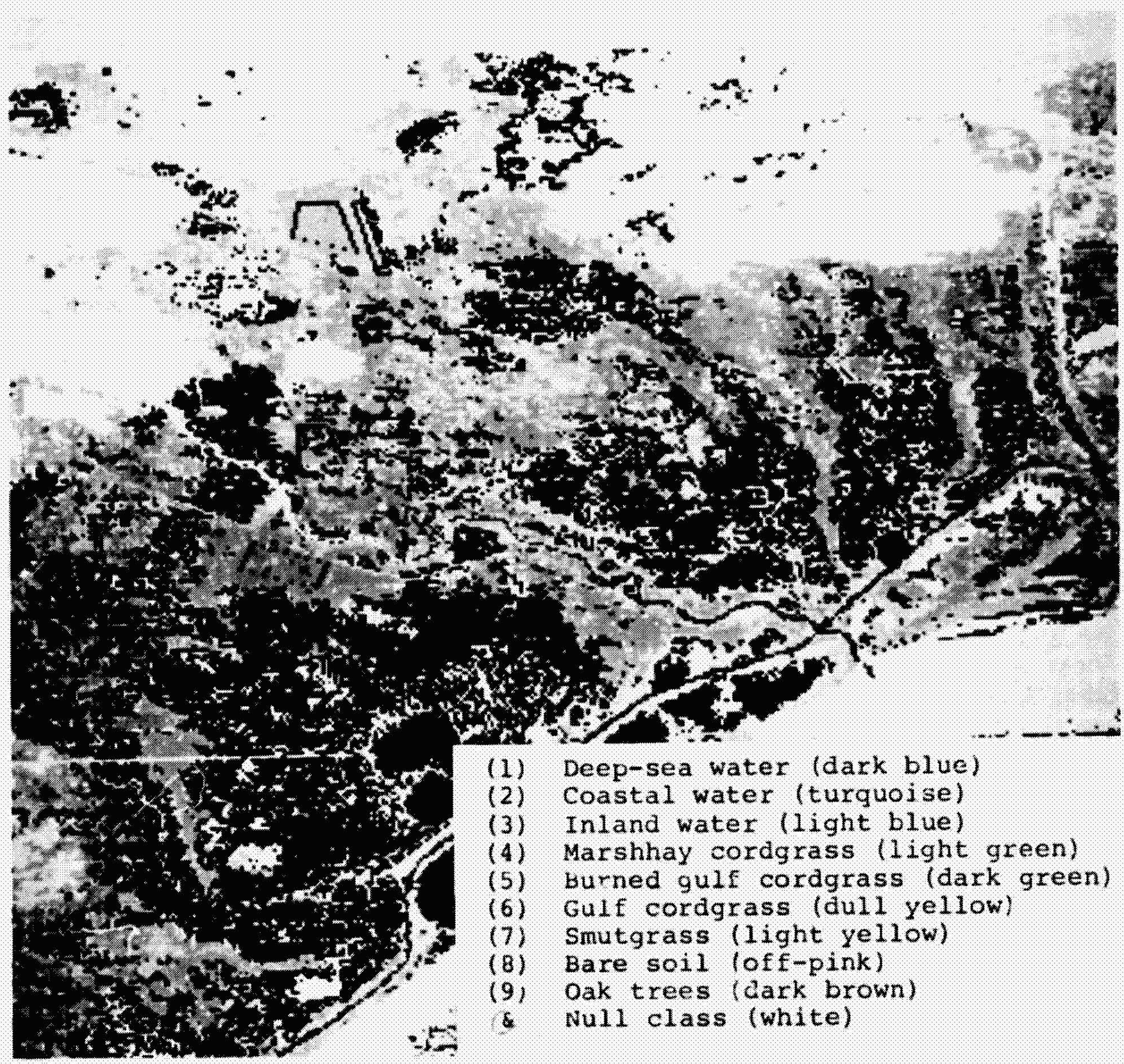

Figure I-4.— CYBER 73 LARSYS classification of San Bernard-2 data with 2-percent thresholding.

TABLE I-VII.- SB-2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples									
			B	C	G	M	O	S	X	Y	Z	Thres.
B	148	94.6	140	0	0	2	0	0	0	0	0	6
C	36	72.2	0	26	4	1	0	2	0	1	0	2
G	229	86.9	0	8	199	11	2	8	0	0	0	1
M1	85	61.2	1	22	5	52	5	0	0	0	0	0
M2	201	86.1	0	1	3	173	24	0	0	0	0	0
O	165	86.7	0	1	3	13	143	0	0	0	0	5
S	230	95.7	0	1	9	0	0	220	0	0	0	0
X	263	82.5	0	5	0	0	0	0	217	37	0	4
Y	187	81.8	1	13	0	0	0	0	20	153	0	0
Z	910	98.2	0	0	0	0	0	0	0	0	894	16

Overall Classification Accuracy = 84.6

B = Burned gulf cordgrass
C = Bare soil
G = Gulf cordgrass
M1 & M2 = Marshhay cordgrass
O = Oak
S = Smutgrass
X = Coastal water
Y = Inland water
Z = Deep-sea water
Thres. = Thresholded

TABLE I-VIII.- SB-2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples									
			B	C	G	M	O	S	X	Y	Z	Thres.
B	218	77.5	169	9	0	14	0	0	2	10	0	14
C	44	25.0	0	11	15	2	8	0	0	2	0	6
G	182	59.9	0	5	109	41	21	2	0	0	0	4
M	88	65.9	1	14	9	58	6	0	0	0	0	0
Whole Test Area	129.20		9,440	15,705	14,314	13,726	3,770	5,144	4,133	4,054	10,803	4,811

Overall Classification Accuracy = 57.1

B = Burned gulf cordgrass C = Bare Soil Thres. = Thresholded

M = Marshhay cordgrass G = Gulf cordgrass

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Figure I-5.– CYBER 73 LARSYS classification of Snook-1/2 temporal data with 2-percent thresholding.

TABLE I-IX.- SNOOK-1/2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples										
			B	C	D	H	M	O	P	W	X	Z	Thres.
B	219	93.2	204	0	1	0	0	0	0	0	0	0	14
C	56	98.2	0	55	1	0	0	0	0	0	0	0	0
D	94	83.0	0	4	78	0	0	0	0	5	5	0	2
H	170	95.9	1	0	1	163	1	0	2	0	0	0	2
M	93	79.6	0	0	1	0	74	0	14	2	0	0	2
O	250	96.8	0	0	0	0	1	242	5	0	0	0	2
P	55	89.1	0	0	0	1	3	1	49	0	0	0	1
W	42	83.3	0	0	3	0	1	0	0	35	2	0	1
X	25	92.0	0	0	0	0	0	0	0	2	23	0	0
Z	399	98.0	0	0	0	0	0	0	0	0	0	391	8

Overall Classification Accuracy = 90.9

B = Bottomland

C = Bermuda, class A

D = Bermuda, class b

H = Bottomland hardwood

M = Mesquite

O = Oak (dense)

P = Oak (sparse)

W = Abandoned cropland, class A

X = Abandoned cropland, class B

Z = Water

Thres. = Thresholded

TABLE I-X.- SNOOK-1/2 SECOND-ORDER CLASSIFICATION PERFORMANCE OF TEST FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples										
			B	C	D	H	M	O	P	W	X	Z	Thres.
C1	24	54.2	0	13	0	0	8	0	0	0	0	0	3
C2	60	31.7	0	19	0	0	3	4	1	0	0	0	33
D	39	41.0	1	3	16	0	1	0	0	4	2	0	12
H	143	72.0	0	0	0	103	0	9	22	0	0	0	9
O	87	27.6	0	0	0	9	0	24	16	0	0	0	38
X	67	22.4	0	1	2	0	0	0	0	2	15	0	47
Z	119	98.3	0	0	0	0	0	0	0	0	0	117	2
Whole Test Area	122,500		1,318	5,406	6,094	4,836	12,249	6,149	11,811	3,634	2,765	1,873	66,365

Overall Classification Accuracy = 49.6

C1 = Bermuda, class A, field 1
C2 = Bermuda, class A, field 2
D = Bermuda, class B
H = Bottomland hardwood
O = Oak
X = Abandoned cropland, class B
Z = Water
Thres. = Thresholded

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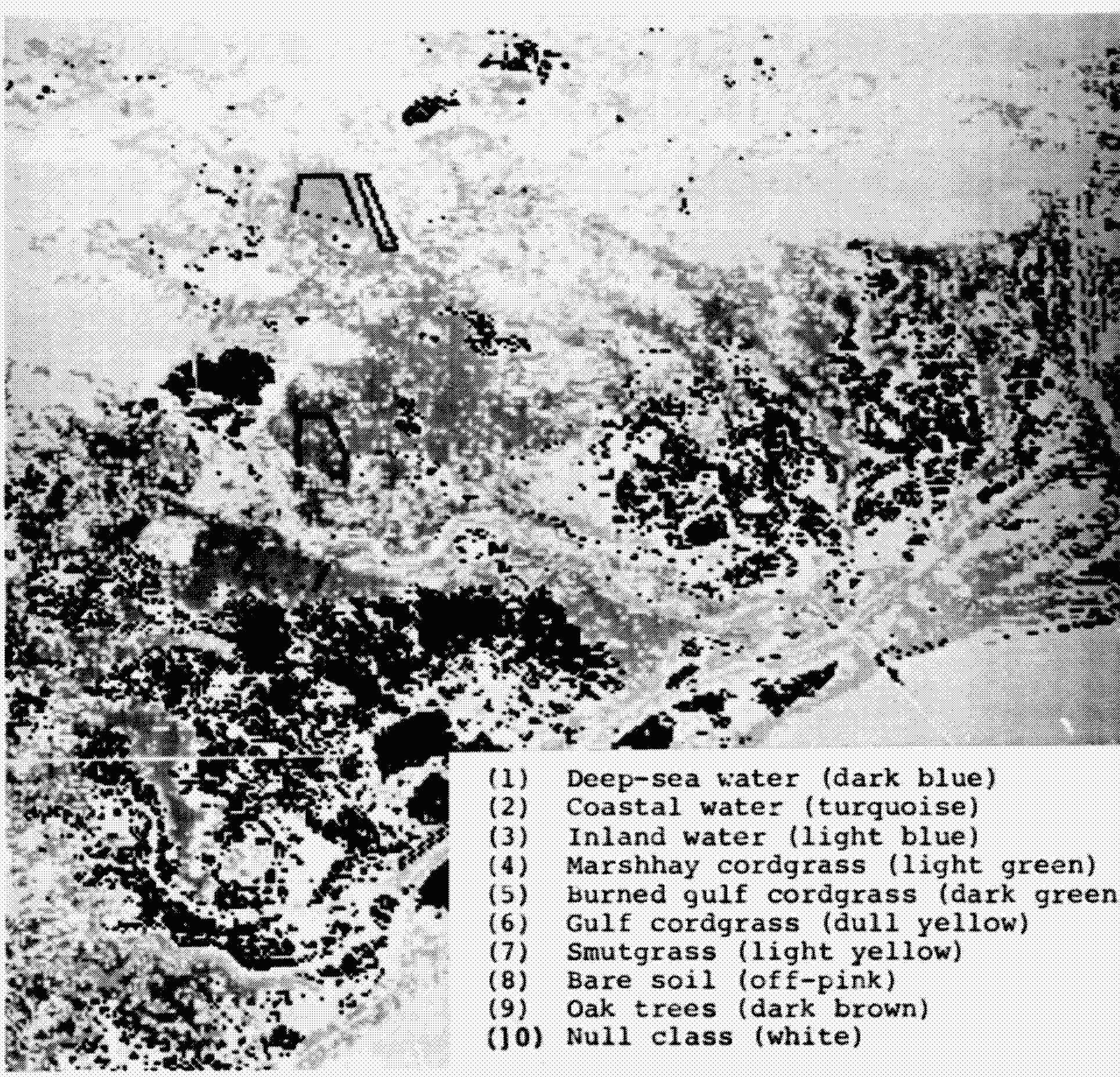

Figure I-6.- CYBER 73 LARSYS classification of San Bernard-1/2 temporal data with 2-percent thresholding.

TABLE I-XI.- SB-1/2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples									
			B	C	G	M	O	S	X	Y	Z	Thres.
B	148	98.0	145	0	0	1	0	0	0	0	0	2
C	36	88.9	0	32	0	0	0	0	0	0	0	4
G	229	96.9	0	0	222	1	0	3	0	0	0	3
M1	85	91.8	0	0	0	78	0	0	0	0	0	7
M2	201	99.5	1	0	0	200	0	0	0	0	0	0
O	165	96.4	0	0	0	0	159	0	0	0	0	6
S	230	93.5	0	1	10	0	0	215	0	0	0	4
X	263	93.9	0	0	0	0	0	0	247	0	0	16
Y	187	95.7	0	0	0	0	0	0	0	179	0	8
Z	190	98.2	0	0	0	0	0	0	0	0	894	16

Overall Classification Accuracy = 95.3

B = Burned gulf cordgrass
M1 & M2 = Marshhay cordgrass
C = Bare Soil
O = Oak
G = Gulf cordgrass

S = Smutgrass
X = Coastal water
Thres. = Thresholded
Y = Inland water
Z = Deep-sea water

TABLE I-XII.- SB-1/2 SECOND-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TEST FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples									
			B	C	G	M	O	S	X	Y	Z	Thres.
B	218	60.1	131	1	0	17	0	0	0	0	0	69
C	44	65.9	0	29	0	0	0	0	0	0	0	15
G	182	87.9	0	1	160	0	0	2	0	0	0	19
M	88	85.2	1	1	0	75	0	0	0	0	0	11
Whole Test Area	129,200		3,749	12,252	12,405	6,148	891	2,538	1,851	745	4,235	84,386

Overall Classification Accuracy = 74.8

B = Burned gulf cordgrass C = Bare soil

M = Marshhay cordgrass G = Gulf cordgrass

Thres. = Thresholded

TABLE I-XIII.- SNOOK-1 FIRST-ORDER CLASSIFICATION PERFORMANCE SUMMARY OF TRAINING FIELDS

Class	No. of Samples	Percent Correct	Distribution of Samples				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
B	219	90.0	197	17	0	0	5
C	56	93.0	0	52	0	3	1
D	94	95.0	3	89	0	2	0
H	170	95.0	0	8	0	161	1
M	93	90.0	0	10	0	83	0
O	250	99.0	0	0	0	247	3
P	55	85.0	0	8	0	47	0
W	42	81.0	0	34	0	8	0
X	25	96.0	0	24	0	1	0
Z	399	95.0	0	0	379	0	20

Overall Classification Accuracy = 91.9 percent

BOTTOMLAND = Bottomland (B)
OPEN RANGE = Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)
WOODLAND = Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)
WATER = Water (Z)

TABLE I-XIV.- SNOOK-1 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TRAINING CATEGORIES

CATEGORY	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
BOTTOMLAND	219	90.0	197	17	0	0	5
OPEN RANGE	217	92.0	3	199	0	14	1
WATER	399	95.0	0	0	379	0	20
WOODLAND	568	95.0	0	26	0	538	4

Overall Classification Accuracy = 93.0 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XV.- SNOOK-1 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TEST FIELDS

CLASS	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
C1	24	58.0	0	14	0	10	0
C2	60	78.0	0	47	0	12	1
D	39	85.0	2	33	0	4	0
H	143	92.0	0	9	0	132	2
O	87	84.0	0	1	0	73	13
X	67	73.0	0	49	0	0	18
Z	247	90.0	0	14	0	218	15
WHOLE TEST AREA	122,500		3,566	44,245	1,767	47,724	2,578

Overall Classification Accuracy = 80.0 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XVI.- SNOOK-1 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TEST CATEGORIES

CATEGORY	SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
OPEN RANGE	245	71.0	2	173	0	49	21
WATER	119	90.0	0	0	107	0	12
WOODLAND	247	90.0	0	14	0	218	15
WHOLE TEST AREA	122,500		3,566	44,245	1,787	47,724	25,178

Overall Classification Accuracy = 83.7 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XVII.- SNOOK-2 FIRST-ORDER CLASSIFICATION PERFORMANCE

CLASS	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
B	219	86.0	189	7	0	21	2
C	56	100.0	0	56	0	0	0
D	94	91.0	0	86	0	5	3
H	170	95.0	6	0	0	162	2
M	93	70.0	3	25	0	65	0
O	250	99.0	0	0	0	248	2
P	55	93.0	3	1	0	51	0
W	42	95.0	0	40	0	1	1
X	25	84.0	1	21	0	3	0
Z	399	97.0	0	0	388	0	11

Overall Classification Accuracy = 91.0 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XVIII.- SNOOK-2 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TRAINING CATEGORIES

CATEGORY	NO. OF SAMPLES	CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
BOTTOMLAND	219	86.0	189	7	0	21	2
OPEN RANGE	217	94.0		203	0	9	4
WATER	399	97.0	0	0	388	0	11
WOODLAND	568	93.0	12	26	0	526	4

Overall Classification Accuracy = 92.5 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XIX.- SNOOK-2 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TEST FIELDS

CLASS	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
C1	24	92.0	0	22	0	2	0
C2	60	57.0	0	34	0	13	13
D	39	59.0	0	23	0	7	9
H	143	85.0	17	0	0	121	5
O	87	78.0	2	2	0	68	15
X	67	67.0	0	45	0	11	11
Z	119	98.0	0	0	117	0	2
WHOLE TEST AREA	122,500		6,579	37,657	2,796	47,949	27,519

Overall Classification Accuracy = 76.6 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XX.- SNOOK-2 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TEST CATEGORIES

CATEGORY	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
OPEN RANGE	245	61.0	0	149	0	51	45
WATER	119	98.0	0	0	117	0	2
WOODLAND	247	81.0	20	5	0	199	23
WHOLE TEST AREA	122,500		6,579	37,657	2,796	47,949	27,519

Overall Classification Accuracy = 80.0 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XXI.- SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TRAINING CATEGORIES

CATEGORY	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
BOTTOMLAND	219	93.0	204	1	0	0	14
OPEN RANGE	217	98.0	0	213	0	1	3
WATER	399	98.0	0	0	391	0	8
WOODLAND	568	98.0	1	4	0	556	7

Overall Classification Accuracy = 96.8 percent

BOTTOMLAND: Bottomland

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XXII.- SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TEST FIELDS

CLASS	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
C1	24	54.0	0	13	0	8	4
C2	60	31.0	0	19	0	8	33
D	39	64.0	1	25	0	1	12
H	143	94.0	0	0	0	134	9
O	87	56.0	0	0	0	49	38
X	67	30.0	0	20	0	0	47
Z	119	98.0	0	0	117	0	2
WHOLE TEST AREA	122,500		1,318	17,899	1,873	35,045	66,365

Overall Classification Accuracy = 61.0 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XXIII.- SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TEST CATEGORIES

CATEGORY	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
OPEN RANGE	245	39.9	1	95	0	36	113
WATER	119	98.0	0	0	117	0	2
WOODLAND	247	77.0	0	0	0	191	56

Overall Classification Accuracy = 71.3 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XXIV.- SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TEST CATEGORIES

CATEGORY	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
OPEN RANGE	245	39.9	1	95	0	36	113
WATER	119	98.0	0	0	117	0	2
WOODLAND	247	77.0	0	0	0	191	56

Overall Classification Accuracy = 71.3 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

TABLE I-XXV.- SNOOK-1/2 FIRST-ORDER CLASSIFICATION PERFORMANCE

SUMMARY OF TRAINING FIELDS

CLASS	NO. OF SAMPLES	% CORRECT	DISTRIBUTION OF SAMPLES				
			BOTTOMLAND	OPEN RANGE	WATER	WOODLAND	THRESHOLDED
B	219	93.0	204	1	0	0	14
C	56	100.00	0	56	0	0	0
D	94	98.0	0	92	0	0	2
H	170	94.0	1	1	0	166	2
M	93	95.0	0	3	0	88	2
O	250	99.0	0	0	0	248	2
P	55	98.0	0	0	0	54	1
W	42	95.0	0	40	0	1	1
X	25	100.0	0	25	0	0	0
Z	399	98.0	0	0	391	0	8

Overall Classification Accuracy = 97.0 percent

BOTTOMLAND: Bottomland (B)

OPEN RANGE: Bermuda, class A (C); Bermuda, class B (D); Abandoned cropland, class A (W); Abandoned cropland, class B (X)

WOODLAND : Mesquite (M); Bottomland hardwood (H); Dense oak (O); Sparse oak (P)

WATER : Water (Z)

APPENDIX J

CLUSTER INTERPRETATIONS AND CLASSIFICATION-LIKE CLUSTER MAPS OF ERTS-1 DIGITAL TAPE DATA USING THE NONSUPERVISED CLASSIFICATION PROGRAM ISOCLS

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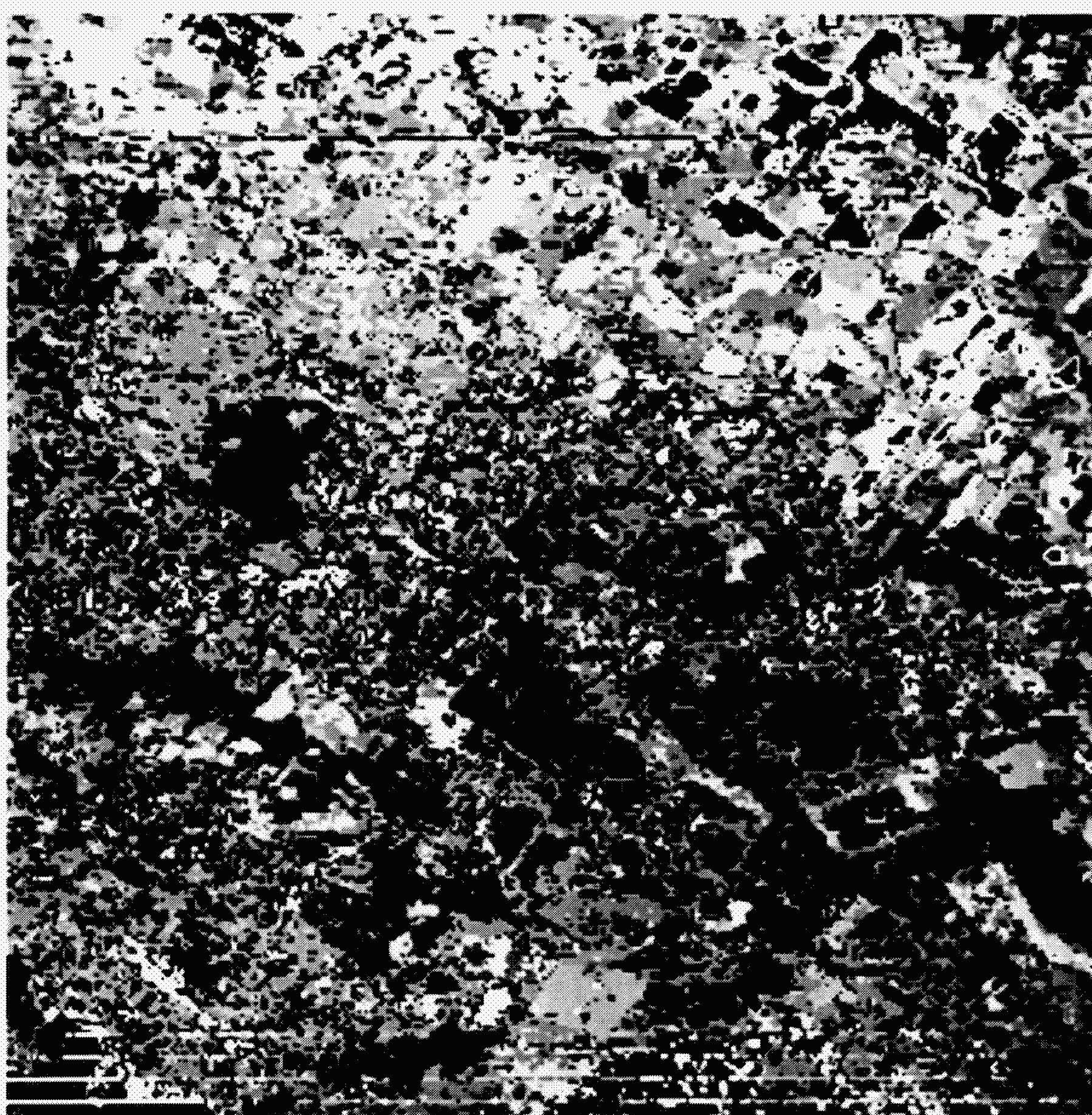

Figure J-1.– Nonsupervised classification map of Snook-1 data using the ISOCLS clustering program (10 major clusters; parameter values in this ISOCLS run were DLMIN = 3.2, STDMAX = 3.0, ISTOP = 10). Reference Table J-I.

TABLE J-I.- SNOCK-1 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-1

Cluster Color	Light Green	Dark Green	Dark Brown	Medium Green	Turquoise	Red	Blue	Yellow	Light Brown	Off-white
Statistics	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.
Channel 1	32.4 / 1.5	35.6 / 1.6	29.7 / 1.5	32.8 / 1.9	33.9 / 2.2	32.1 / 1.3	27.5 / 1.8	32.4 / 1.9	38.0 / 1.8	39.4 / 2.2
Channel 2	25.4 / 1.9	30.4 / 2.1	21.3 / 2.0	25.1 / 2.3	29.0 / 3.1	21.2 / 2.7	17.3 / 1.9	23.5 / 2.5	33.2 / 2.7	38.7 / 2.8
Channel 3	41.3 / 2.3	44.0 / 2.3	36.8 / 2.8	48.0 / 2.4	33.2 / 3.5	79.7 / 4.2	13.6 / 4.2	56.8 / 3.3	50.4 / 2.5	44.3 / 4.2
Channel 4	22.2 / 1.5	23.2 / 1.6	20.5 / 1.5	26.4 / 1.6	17.5 / 3.3	46.1 / 2.1	4.2 / 2.6	32.0 / 2.3	26.3 / 1.6	22.5 / 2.6
Population	30,149	16,998	31.096	13,838	7,742	1,319	2,115	5,784	4,726	2,990
Interpretation	Open range, grassland	Abandoned croplands; open range, sparsely vegetated	Woods, post oak	Open grassland, bermuda fields, greener than the light green cluster	Wet bottomland (nonwoodland)	Cropland, very vigorously growing	Water (Lake Somerville)	Cropland, not as vigorous as the red cluster	Grassland, sparse and dry	Bare soil, asphalt

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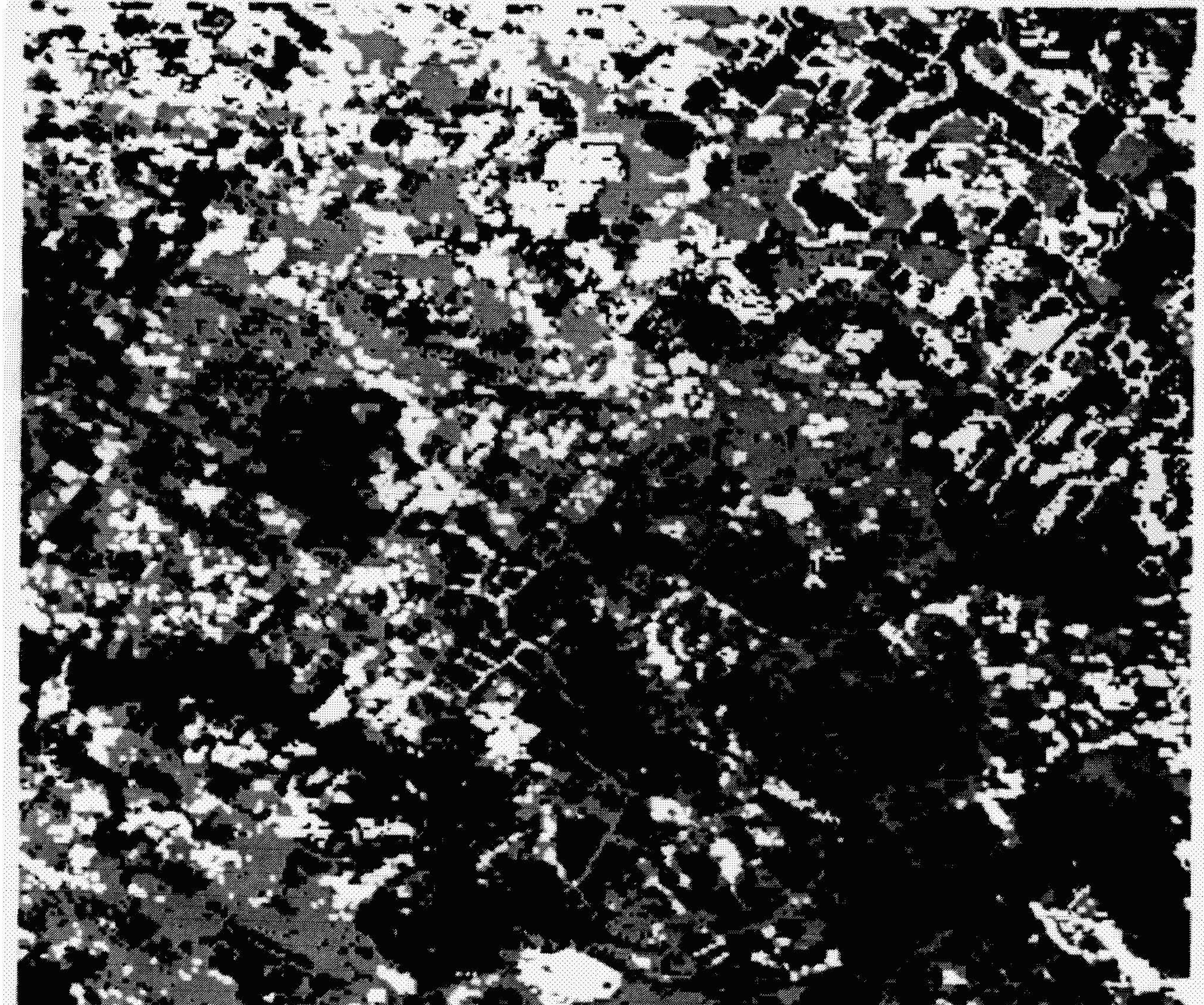

Figure J-2.- Nonsupervised classification map of Snook-1 data using the ISOCLS clustering program (five clusters; parameter values in this ISOCLS run were DLMIN = 0, STDMAX = 4.5, MAXCLS = 5, ISTOP = 10). Reference Table J-II.

TABLE J-II.- SNOOK-1 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-2

Cluster Color	Red	Dark Brown	Bluish Green	Blue	Yellow
Statistics	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.
Channel 1	33.7 / 9.0	30.4 / 1.8	34.7 / 2.3	24.3 / 9.3	35.1 / 4.0
Channel 2	24.5 / 10.6	22.4 / 2.4	29.5 / 5.2	15.4 / 6.2	29.0 / 7.0
Channel 3	69.0 / 9.3	37.8 / 4.2	41.3 / 4.6	10.0 / 6.5	49.9 / 3.5
Channel 4	38.2 / 6.0	20.9 / 2.3	21.9 / 2.6	3.9 / 3.3	26.9 / 2.3
Population	6,048	49,970	38,829	2,878	24,775
Interpretation	Cropland, very vigorously growing	Woods, post oak	Nonwooded open range; grassland	Water (Lake Somerville)	Nonwooded open range and vegetated land, brighter in IR than the green cluster

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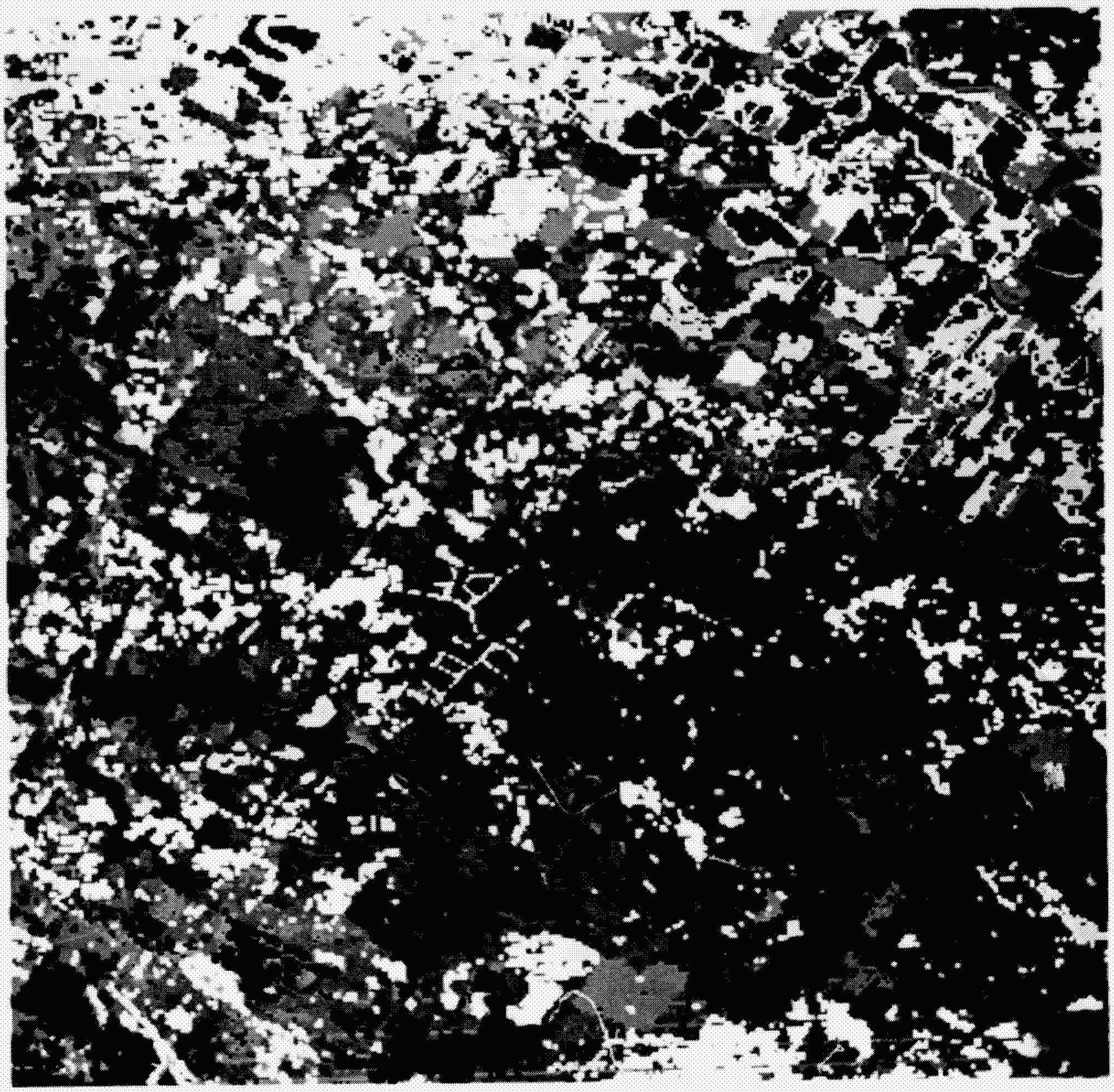

Figure J-3.- Nonsupervised classification map of Snook-1 data using the ISOCLS clustering program (eight clusters; parameter values in this ISOCLS run were DLMIN = 0, STDMAX = 4.5, MAXCLS = 8, ISTOP = 10). Reference Table J-III.

TABLE J-III.- SNOOK-1 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-3

Cluster Color	White	Dark brown	Turquoise	Blue	Off-white	Red	Green	Yellow
Statistics	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.
Channel 1	66.3 / 18.5	29.9 / 1.6	34.4 / 2.2	28.0 / 2.3	38.3 / 3.0	32.0 / 1.9	33.2 / 1.9	32.8 / 2.1
Channel 2	65.7 / 16.6	21.7 / 2.3	29.8 / 4.2	17.9 / 2.8	35.4 / 7.0	22.3 / 3.8	26.6 / 3.3	24.6 / 3.4
Channel 3	70.4 / 14.7	37.0 / 3.0	33.8 / 5.4	11.8 / 6.0	47.4 / 4.5	72.5 / 7.6	43.0 / 2.5	52.6 / 4.0
Channel 4	33.6 / 5.8	20.5 / 1.7	18.2 / 3.6	5.5 / 5.4	24.5 / 2.2	40.5 / 5.8	23.0 / 1.7	29.3 / 2.7
Population	384	36665	9529	2727	14044	4042	41857	12902
Interpretation	Clouds	Woods, post oak	Wetland, wet bottomland	Water (Lake Somerville)	Grassland, sparse, dry; bare soil, clay	Cropland very vigorously growing	Open range; grassland bermuda fields	Cropland, not as vigorous as the red cluster; also some grassland

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Figure J-4.- Classification map of Snook-1 data obtained by a manipulation of the clustering results of figure J-2. [Spectrally similar clusters are grouped together to form (1) vigorously growing cropland (red), (2) water (blue), (3) other, including rangeland (off-pink)].

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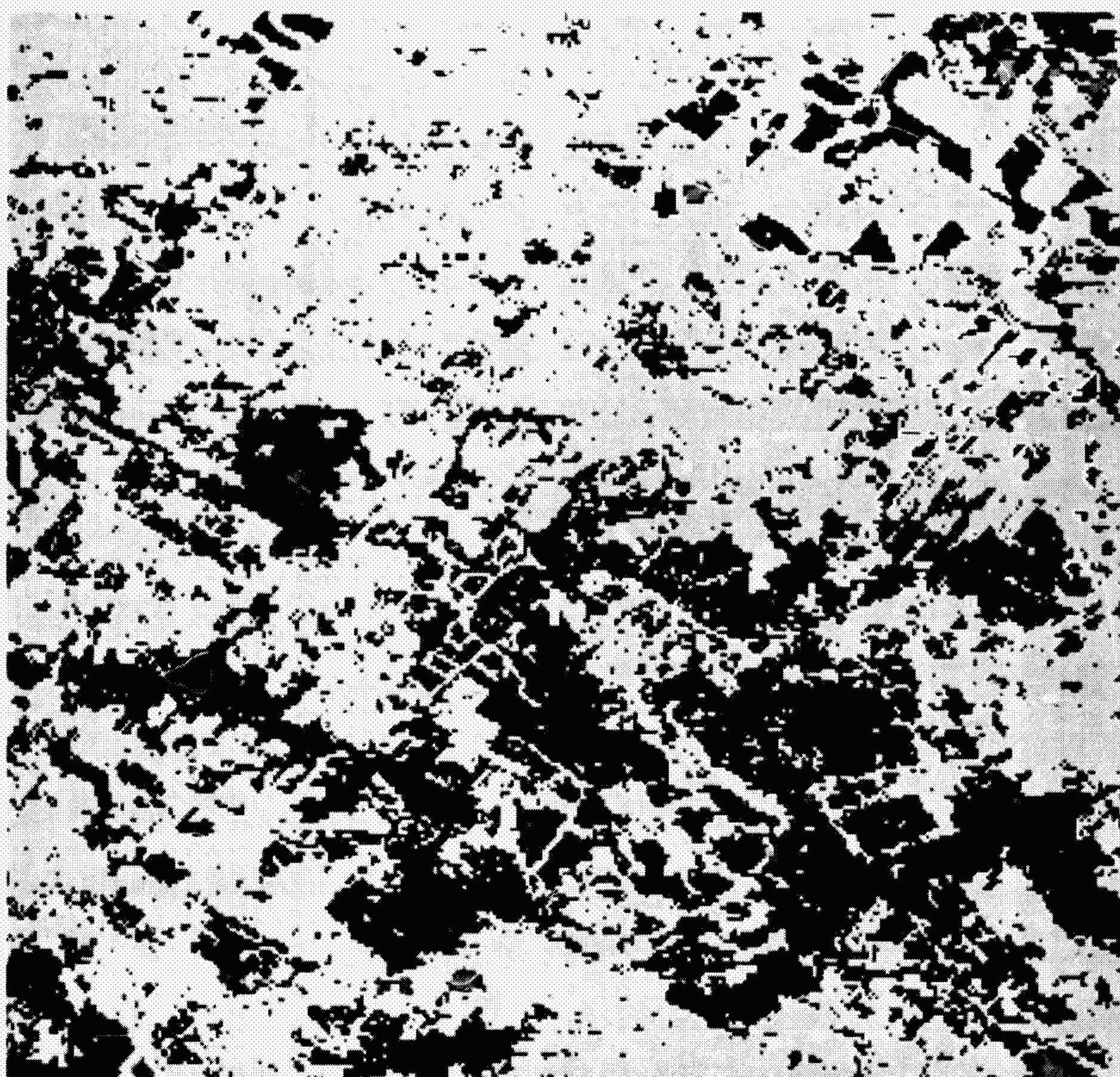

Figure J-5.- First-order classification map of Snook-1 data obtained by manipulation of the clustering results of figure J-3 [clusters that belong to the same classes are grouped together to form (1) vigorously growing cropland (red), (2) water (blue), (3) clouds (white), (4) rangeland, woodland (brown), (5) rangeland, open rangeland and grassland (green)].

NASA S-73-28025

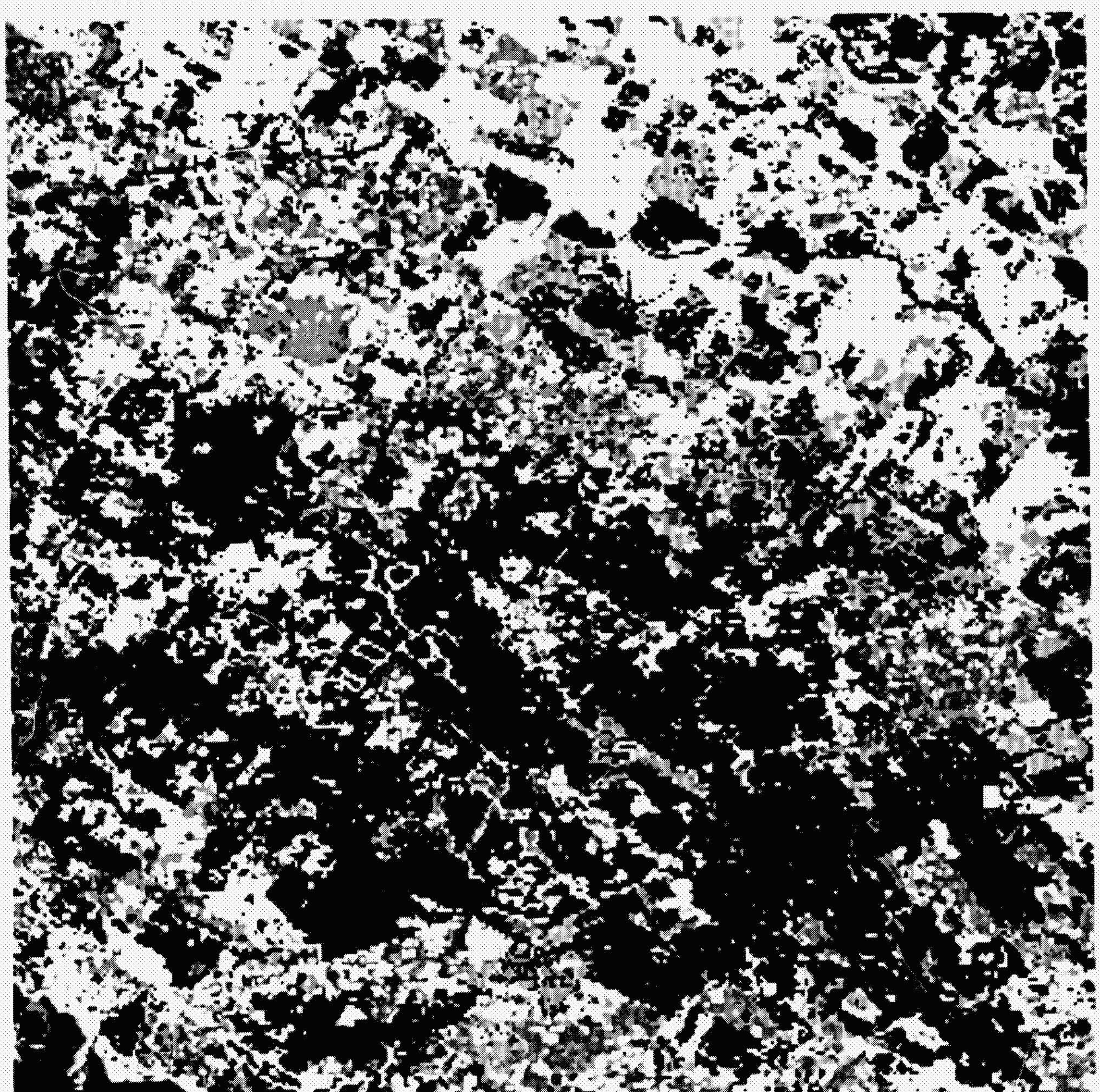

Figure J-6.- Nonsupervised classification map of Snook-2 data using the ISOCLS clustering program (10 clusters; parameter values in this ISOCLS run were DLMIN = 0, STDMAX = 3.0, MAXCLS = 10, ISTOP = 10). Reference Table J-IV.

TABLE J-IV.- SNOOK-2 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-6

Cluster Color	Off-white	Medium brown	Light green	Dark brown	Red	Turquoise	Green	Orange	Blue	Off-pink
Statistics	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.
Channel 1	30.3 / 3.2	20.3 / 1.2	22.8 / 1.3	19.7 / 1	21.7 / 1.4	21.1 / 1.7	25.5 / 1.2	22.9 / 1.3	15.3 / 5.5	26.0 / 1.4
Channel 2	31.3 / 4.2	15.9 / 1.6	20.7 / 1.3	15.1 / 1.6	14.6 / 2.1	17.5 / 2.5	23.2 / 2.0	19.8 / 1.9	8.8 / 3.2	25.1 / 2.0
Channel 3	35.2 / 3.5	23.6 / 1.4	24.1 / 1.8	20.1 / 1.2	40.9 / 4.9	17.4 / 1.9	32.5 / 2.1	28.8 / 1.9	5.1 / 0.7	27.1 / 1.9
Channel 4	17.6 / 2.0	13.0 / 0.9	12.7 / 1.3	11.2 / 0.9	24.4 / 3.7	8.3 / 1.5	17.6 / 1.4	15.8 / 1.3	0.8 / 0.7	13.8 / 1.9
Population	2162	25469	25185	25686	201[illegible]	4220	10157	15256	3322	9027
Interpretation	Bare, bright, sandy soil, sometimes with a thin grass cover (bermuda)	Woodland with open, grass understory	Poor grass-land; forb/grass mix-tures; abandoned cropland; threeawn	Woodland with yaupon or other brush understory	Cropland, growing; very vigorously	Wet bottomland; wet meadow	Grassland (fairly pure stand of bermuda, dallis grass, etc.; good condition; slightly more vigorous more vigorous than the yellow cluster)		Water (Lake Somerville)	Bare soil, moist (e.g. moist, plowed fields) in mixed roselms; also, dry bare soil & dark mat. or roads

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Figure J-7.- Nonsupervised classification map of SB-1 data using the ISOCLS clustering program (eight major clusters; parameter values in this ISOCLS run were DLMIN = 0, STDMAX = 4.5, MAXCLS = 15, ISTOP = 10). Reference Table J-V.

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TABLE J-V.- SB-1 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS OF FIGURE J-7

Cluster Color	Turquoise	Dull yellow	Deep blue	Light green	Light yellow	Medium dark blue	Dark green	Brown
Statistics	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.
Channel 1	34.8 / 2.6	29.5 / 1.7	25.7 / 2.8	28.8 / 1.7	30.9 / 2.1	30.8 / 2.2	27.4 / 1.8	25.8 / 1.4
Channel 2	26.8 / 2.4	21.8 / 1.9	14.2 / 1.8	21.9 / 2.2	22.9 / 2.5	20.7 / 2.4	20.0 / 2.3	16.2 / 1.8
Channel 3	16.5 / 2.6	40.2 / 2.2	8.5 / 2.3	29.9 / 2.5	46.3 / 2.8	12.1 / 2.2	21.9 / 2.7	35.6 / 2.6
Channel 4	4.1 / 1.7	20.6 / 1.5	1.8 / 1.2	14.3 / 1.8	24.2 / 1.7	2.7 / 1.2	9.1 / 1.8	19.8 / 1.7
Population	5891	21866	14593	14891	19205	5394	13778	12667
Interpretation	Coastal, shallow water, perhaps turbid	Mixture of smut-grass and gulf cordgrass	Deep sea water (Gulf of Mexico)	Mixture of marshhay and burned area; wetland	Mixture of smut-grass and gulf cordgrass	Medium deep water	Mixture of marshhay and burned wetland	Woods

NASA S-73-28322

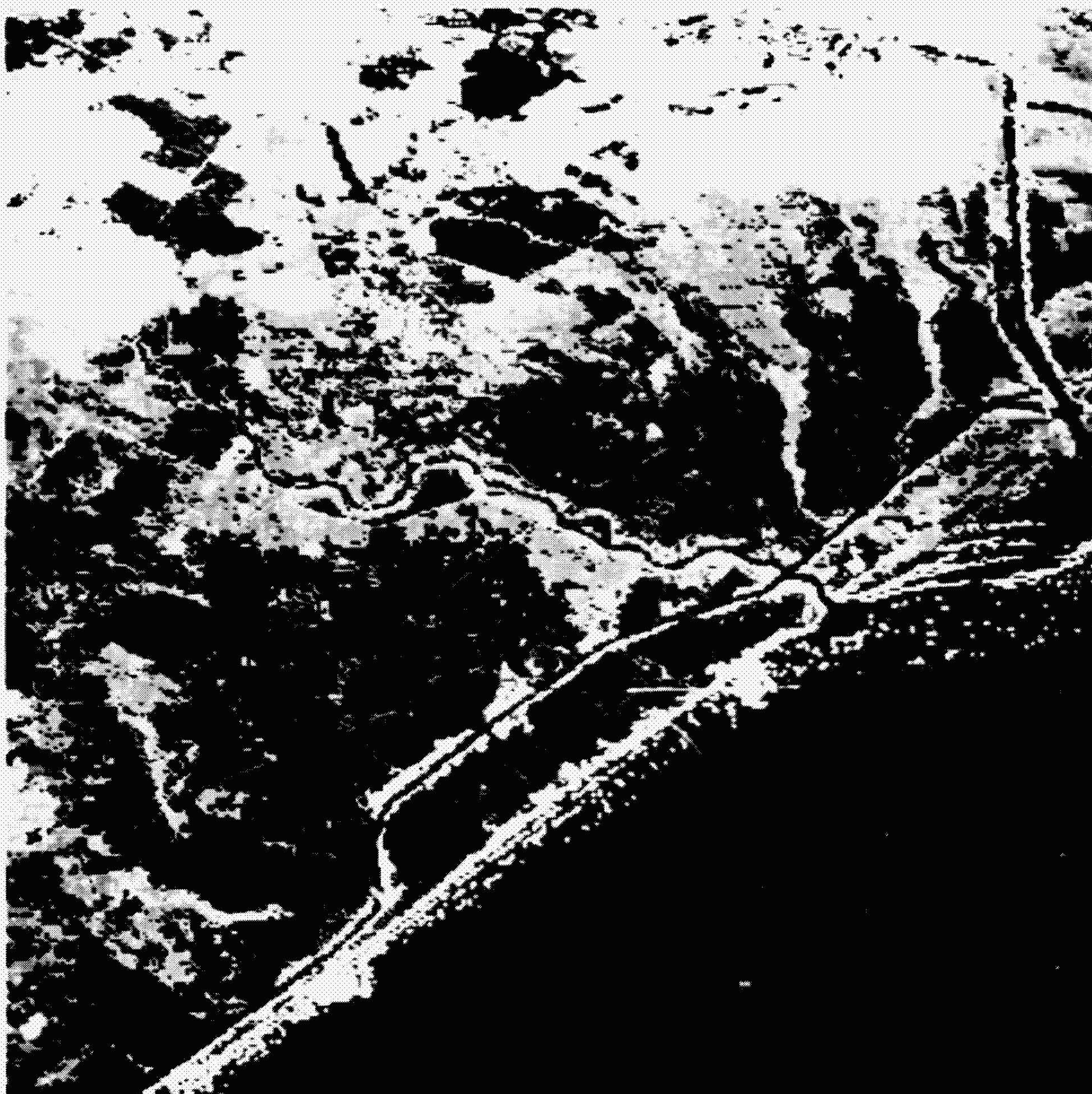

Figure J-8.- Nonsupervised classification map of SB-2 data using the ISOCLS clustering program (seven major clusters; parameter values in this ISOCLS run were DLMIN = 0, STDMAX = 3.0, MAXCLS = 15, ISTOP = 10). Reference Table J-VI.

TABLE J-VI.- SB-2 DATA INTERPRETATION AND STATISTICS OF THE CLUSTERS IN FIGURE J-8

Cluster Color	Light yellow	Dull yellow	Light green	Dark green	Purple	Blue (four shades)	White (and off-white)
Statistics	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.	mean / st. dev.
Channel 1	26.8 / 1.8	23.9 / 1.0	21.8 / 1.2	20.8 / 1.2	24.3 / 1.2	(Individual cluster statistics of these two categories are not reported here because these clusters are not of much interest)	
Channel 2	22.0 / 2.0	18.6 / 1.5	15.9 / 1.2	14.7 / 1.3	19.2 / 1.4		
Channel 3	(Channel 3 was not used in the clustering process because it was noisy.)						
Channel 4	18.3 / 2.2	14.7 / 1.9	12.1 / 2.0	7.5 / 1.6	9.5 / 2.2		
Population	7,347	15,893	16,542	17,792	10,299	40,492	24,635
Interpretation	Smutgrass mixed with gulf cordgrass	Mostly gulf cordgrass	Marshhay cordgrass	Burned areas and marshhay cordgrass	Wetland, wet soil	Water	Clouds and urban areas